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NUTRIENT REQUIREMENTS FOR GROWTH AND ANTLER DEVELOPMENT IN THE WHITE-TAILED DEER [1]

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Pennsylvania, in common with other states fortunate enough to possess a wealth of wildlife and a suitable habitat for its continued existence, has been faced with an ever increasing game management problem. This is especially true of the white-tailed deer (*Odocoileus virginianus*) since it involves not only recreational and esthetic considerations but also the economics of forest management, damage to orchards and farm crops, and the sanitation of watersheds.

Sound management procedures must be based on accurate field observations and adequate knowledge of the nutritional needs of the species. Fortunately the frequency, scope, and accuracy of field studies have been constantly increasing during the past two decades and a wealth of reliable information is now available from this source in regard to such items as seasonal plant varieties preferred by deer; deer carrying capacity of the range; and aging, weighing and other physiological data from hunt and highway-killed animals.

Experimental feeding studies with deer have been rather few in number, however because of the great difficulty and expense as well as the long period of time required and the consequent delay in applicability of results. Forbes and Bechdel (1930) and Forbes and Overholts (1931) investigated the feeding value of laurel and rhododendron for fawns. Maynard *et al.* (1935) conducted feeding studies over a four-year period which were particularly directed toward the alleviation of starvation in Adirondack white-tailed deer. Nichol (1938) determined the quantities of native Arizona forage necessary for growth, maintenance and reproduction of mule deer and Arizona white-tailed deer. Davenport (1939) in Michigan winter feeding trials with white-tailed deer, found that 3 to 4 pounds of good air-dry forage was needed daily to prevent extensive weight loss. Forbes *et al.* (1941) conducted digestibility trials of dogwood and willow browse, acorns, and a number of domestic animal rations with young white-tailed deer. Latham (1950) reported a close relationship between food intake and body size, the number of fawns born to mature does, and antler development in male white-tailed deer. Bissell *et al.* (1955) investigated the digestibility of natural and artificial foods with California deer.

Conspicuous by their absence are reports concerning the qualitative and quantitative requirements of essential nutrients, minerals and vitamins for deer, yet the importance of such information is well attested to in the extensive literature for the various domestic species. In addition to the overall lack of sufficient food, specific deficiencies of energy, protein, calcium, phosphorus, cobalt and vitamin A have been shown to produce

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symptoms of undernutrition in domestic ruminants; and the possibility that one or more of these are contributing to the subnormal growth, antler development and reproduction of Pennsylvania deer should not be overlooked.

Accordingly, the work presented in this report was planned as a cooperative research project, with the Pennsylvania Cooperative Wildlife Research Unit, the Pennsylvania Game Commission and the Department of Zoology and Entomology, to investigate the influence of specific deficiencies of energy, protein, sulfur-containing amino acids, sulfur, calcium, phosphorus, calcium and phosphorus combined, and vitamins A and D on the body growth and antler development of male white-tailed deer (French *et al.* 1955).

General Procedure

Twenty pens, 12 x 28 feet, each suitable for 2 deer, were fenced in with stock wire to a height of 8 feet. They were erected in a secluded area along the western edge of a stand of white pine trees on a gentle downhill slope that afforded good drainage. A 3-foot runway was fenced in along the front of the pens and a feed shed, 10 x 18 feet, was constructed about midway of this. A heavy duty Toledo platform scale was mounted on a concrete foundation at one end of the feed shed. The floating platform was enlarged and enclosed by a wooden cage $2\frac{1}{2}$ feet wide, 4 feet long and 5 feet high, with a gate that could be opened from either side to guide the deer onto the scale. The deer were weighed at approximately 2-week intervals throughout the experiment. A good supply of deep well water was available from an adjacent reservoir and was supplied to the deer in shallow 4-gallon buckets which were cleaned and refilled daily. Two-compartment feeder boxes, 12 x 24 x 6 inches deep, were constructed from heavy oak boards and fitted with hinged sloping roofs that protected the food from rain and snow. The over-hang of the roof was also effective in preventing spilling of food by excessive head-tossing during feeding. Lean-to type open shelters for wind and rain protection, consisting of a 4-foot-square wooden framework covered with corrugated metal roofing, were placed in the rear of each pen under the trees.

New fawns were first fed warm skim-milk in amounts up to 10 ounces per feeding 4 times a day, using ordinary baby bottles with slits cut in the rubber nipples, and later were taught to drink from pails. Since the incidence of diarrhea or scouring was quite high a change was soon made to raw whole milk, and in severe cases colostrum milk or Suldistat, a bacteriostatic and absorptive preparation, was used quite successfully. The greatest health problem encountered with several of the fawns was severe bloating. A carminative mixed in the milk was quite effective as a suppresive although one fawn died from a ruptured abomasum. In addition to bloat and diarrhea which were constant problems with many of the young fawns, fright and panic at sudden unfamiliar noises and odors were responsible for a number of later injuries including a broken leg, a broken neck, and bruises and lacerations from collision with the wire fence. The broken leg of Fawn 123 was successfully healed by the application of a splint and plaster cast. Cuts and bruises healed rapidly without treatment.

Green, leafy alfalfa hay and calf-starter feed were constantly available to the fawns and were consumed by them in small amounts as early as two weeks of age. The calf-starter feed consisted of a mixture of 100 pounds crimped oats, 100 pounds wheat bran, 100 pounds cracked corn, 1.5 pounds salt, and 0.8 pounds of Quadrex vitamin mixture. The fawns were also observed to eat grass and leaves and to ruminate when less than a month old. The frequency of milk feeding was reduced to twice a day and the amount increased to 15 ounces per feeding when the fawns were old enough to consume about a pound of hay and grain combined per day. They were weaned at the age of 3 to 4 months when they weighed 30 to 40 pounds.

The fawns were then fed alfalfa hay and calf-starter until October 24, 1952. At that time they were started on a transition period, and were gradually accustomed to the experimental rations by mixing increasing amounts of these diets with decreasing amounts of calf-starter. The alfalfa hay was also fed in decreasing amounts so that by November 16, 1952 all deer were receiving only the experimental rations.

Since they varied in breeding stock, size, age, and area of origin, two deer differing widely in these respects were selected for each experimental pair. The oldest and

TABLE 1.—PERCENTAGE OF COMPONENTS IN RATIONS—FIRST YEAR

Rations Nos.	1A, 1B	1C	2	3	4	5	6	7	8	9	10	11
Ration Descriptions	Complete	Low Energy	Low Calcium	High Calcium	Low Phos.	High Phos.	Low Ca. Low Phos.	A & D Low Ca. Low Phos.	Low Protein Low Sulfur	Low Protein High Sulfur	Med. Protein Low S-amino Acid	Med. Protein High S-amino Acid
Deer Nos.	106 120 117 132	105 113	127 111	115 122	135 137	109 134	104 128	118 126	131 136	123 130	121	124 129
Alfalfa, ground	48	48	–	–	40	40	–	–	–	–	–	–
Straw, wheat, ground	–	–	13	13	–	–	20	20	15	14.5	20	20
Corn meal	34.1	34.1	59	57.4	48.4	45.4	64	64	40	40	29.5	29
Soybean oil meal	5	5	5	5	5	5	10	10	–	–	–	–
Linseed meal	5	5	5	5	–	–	–	–	–	–	2	2
Cottonseed meal	5	5	10	10	–	–	–	–	–	–	–	–
Salt	–	–	1	1	1	1	1	1	1	1	–	–
Salt & Trace Elements	1	1	–	–	–	–	–	–	–	–	1	1
Di-sodium Phosphate	1.9	1.9	2	2	–	3.0	–	–	–	–	–	–
Calcium Carbonate	–	–	–	1.6	0.6	0.6	–	–	–	–	–	–
A & D Oil*	+	+	–	–	–	–	–	+	+	+	+	+
Sodium Sulfate	–	–	–	–	–	–	–	–	–	0.5	–	–
Cane Molasses	–	–	5	5	5	5	5	5	5	5	5	5
Di-calcium Phosphate	–	–	–	–	–	–	–	–	3.0	3.0	2.5	2.5
Cerelose	–	–	–	–	–	–	–	–	35.5	35.5	–	–
Fish-meal	–	–	–	–	–	–	–	–	0.5	0.5	–	–
Wheat, ground	–	–	–	–	–	–	–	–	–	–	30	30
Oats, ground	–	–	5	5	5	5	5	5	5	5	15	15
Methionine	–	–	–	–	–	–	–	–	–	–	–	0.5

* Vitamin A and D oil (3,000 U. S. P. Units A, 300 I. U. (chick) D per gm) added, 28 gm per 25 kg of ration.

youngest pairs were assigned to the control or complete ration with the remaining pairs assigned to the experimental rations at random.

Eleven different experimental rations were compounded (Table 1) to supply both high and low levels of a number of important nutrients that have been shown to affect the growth of domestic ruminants including: energy, calcium, phosphorus, calcium and phosphorus, Vitamins A and D, protein, sulfur, and sulfur-containing amino acids. Ration 1, the control ration, was made as nutritionally complete and as palatable as possible. This was fed to the first two pairs of deer in unrestricted amounts. Ration 1C was identical in composition to Ration 1, but was fed to the next pair at approximately half the amount, to constitute a low energy ration. Rations 2 and 3 differed from each other only in calcium content, with Ration 2 being very low in calcium (0.09%). Rations 4 and 5 differed from each other only in phosphorus content, with Ration 4 being very low in phosphorus (0.27%). Rations 6 and 7 were both very low in calcium (0.08%) and phosphorus (0.26%), but Ration 7 had Vitamin A and D feeding oil added to supply 3000 U.S.P. Units of Vitamin A and 300 International units of Vitamin D per kilo of feed. Rations 8 and 9 were both very low in protein content (4.6%), and Ration 9 was supplemented with sodium sulfate as a source of inorganic sulfur. Rations 10 and 11 were of medium protein content 9.5%, and differed only in the methionine added to Ration 11 to increase the sulfur-containing amino acid content. Chemical analyses of the rations, shown in Table 2, were made on composite samples taken from a number of mixing periods and indicate, that the rations, as fed, varied in nutrient composition as planned.

The deer were fed and watered twice daily. The quantity of feed offered to each pair was adjusted to the amount that they would consume. The feed was weighed with a weighing feed scoop that was checked for accuracy at frequent intervals, and the consumption of each pair of deer was recorded daily.

The winter of 1952–53 was unusually warm and mild with a minimum temperature below 10°F. occurring on only one day.

TABLE 2.—CHEMICAL ANALYSES OF RATIONS—AIR DRY BASIS

Ration	Energy	Nitrogen	Protein	Ash	Calcium	Phosphorus	Sulfur
	Cal/gm	%	%	%	%	%	%
1.	3.94	2.68	16.8	8.2	0.64	0.56	0.27
1C.	3.94	2.68	16.8	8.2	0.64	0.56	0.27
2.	4.05	2.19	13.7	5.0	0.09	0.60	0.21
3.	3.96	2.09	13.1	5.9	0.65	0.59	0.21
4.	4.02	2.18	13.6	6.1	0.74	0.27	0.22
5.	4.07	2.18	13.6	7.2	0.73	0.59	0.22
6.	3.98	1.71	10.7	3.8	0.08	0.26	0.17
7.	3.99	1.65	10.3	3.5	0.07	0.25	0.17
8.	3.68	0.73	4.6	4.7	0.73	0.65	0.08
9.	3.64	0.75	4.7	5.2	0.72	0.64	0.20
10.	3.90	1.48	9.3	4.8	0.64	0.68	0.13
11.	3.90	1.55	9.7	4.5	0.55	0.63	0.22

The mean monthly temperatures for December, January, February and March were 32.9, 33.8, 33.8 and 39.0°F. as compared to the normals for these months of 30.0, 27.2, 27.3 and 36.3°F.

RESULTS AND DISCUSSION—FIRST YEAR

Several deer developed a habit of eating their own hair or that of their pair-mates during the winter and spring seasons. This was most noticeable in deer on the severely restricted rations and involved about 30 per cent of body area, but it also occurred in deer on the supplemented diets. Skin and hair scrapings were examined and found to be free of fungus disease or parasites.

The body temperatures of a few healthy deer were measured rectally during the summer and winter seasons of 1952–1953 and were found to average 102.2°F. and 101.4°F., respectively. Blood and feces samples were also obtained and examined. The blood samples showed the presence of sickle-cell erthrocytes and a red cell count of 22 million, confirming the findings of Whitlock (1939) and Maynard *et al.* (1935). The feces samples were normal with no evidence of intestinal parasitic infestation.

Deer consuming Rations 1C (low energy), 4 (low phosphorus), 6 and 7 (low calcium and low phosphorus), and 8 and 9 (low protein) did not completely shed their winter hair until July as contrasted to June for the control and supplemented groups, and were nearly two months later (late October compared to early September) in shedding the reddish summer coat and in growing the heavy dark-gray winter pelage. This finding was associated with other deficiency signs such as subnormal growth, vigor, and antler development.

FOOD CONSUMPTION, GROWTH, AND NUTRIENT REQUIREMENTS—FIRST YEAR—During the first year (Nov. 1952–Oct. 1953) all deer consumed gradually increasing amounts of the experimental rations as shown in Figure 1. The two pair of control deer on

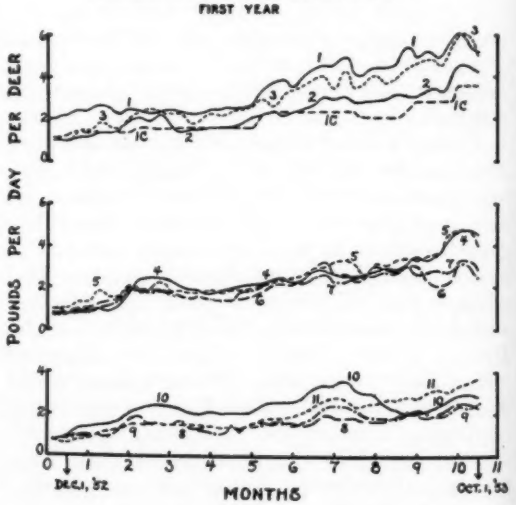

FIG. 1. Average daily food consumption, first year.

Ration 1, the pair on Ration 3 (calcium supplemented) and one deer of the pair on Ration 5 (phosphorus supplemented), however, ate considerably more than did the others. At the start of the experiment when the deer weighed approximately 50 pounds

the average consumption of air-dry food amounted to about one pound per deer per day. This increased to a level of two pounds by the end of January. Food intake then decreased slightly during the late winter months and the deer gained weight very slowly even though the rations were available in unrestricted amounts (with the exception of the pair on Ration 1C, low energy). Through the spring and summer of 1953 food consumption increased again quite steadily to a daily average of about five pounds for the supplemented deer and about three pounds for the nutrient restricted ones.

With the approach of sexual maturity and the rutting season in October, however, another decrease in food consumption and weight occurred, despite the ready availability of all the feed they would consume (See Fig. 1, 2). Greatly increased nervous activity, constant exercising and rubbing of the velvet on matured antlers, increase in size of the testes and broadening of the neck were signs of the hormonal changes occurring at this time which undoubtedly exerted a depressive effect on feed consumption and growth.

The four control deer that were allowed to eat unlimited amounts of the complete Ration 1 ranged in weight from 134 to 180 pounds on October 1, 1953, with an average weight of 155 pounds (Fig. 2). The 2 deer that were restricted in energy to about one-half the amount of this same diet, 1C, weighed only 80 and 115 pounds and were considerably smaller in stature. The wide variation in weight between these two deer may well be a result of one eating more than his share of the ration. The two deer receiving the low calcium Ration 2 weighed 96 and 131 pounds compared to 140 and 152 pounds for the calcium supplemented deer on Ration 3, and a similar difference was demonstrated between the low phosphorus Ration 4 and phosphorus supplemented deer, Ration 5.

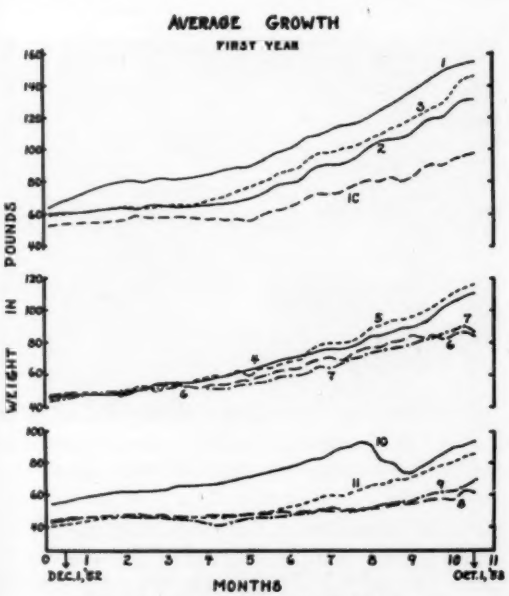

FIG. 2. Average growth, first year.

Very little difference, however, in either weight or food consumption was noted between the deer on Rations 6 and 7, both low in calcium and phosphorus with Vitamins A and D added to Ration 7, or between the deer on Rations 8 and 9 which were low protein diets with added inorganic sulfur in Ration 9. All four deer subsisting on the low protein rations were very small, thin, and light in weight, ranging from 59 to 71 pounds. The deer on the medium protein Rations 10 and 11 ranged in weight from 82 to 93 pounds, with very little benefit from the added methionine in Ration 11. Comparative weight gains for the different diet groups show that deficiencies of energy, protein, calcium, phosphorus, and calcium and phosphorus combined, seriously limited the growth of the deer.

The effect of protein content of the diet on growth is evident in Fig. 2. Deer on Ration 1 which contained 16 per cent protein gained 108 pounds and those on Rations 3 and 5 (13% protein), gained nearly 100 pounds, while the deer on Rations 10 and 11 (9.5% protein) gained about 50 pounds and those on Rations 8 and 9 (4.5% protein) gained only 20–30 pounds. This indicates a protein requirement for young growing deer of 13–16 per cent of the diet.

An estimate of the quantity of food, in terms of energy or weight of air-dry food, required for optimum growth of yearling deer can also be derived from the data presented in Figures 1 and 2. The food intake of the four consuming Ration 1, the two deer on Ration 3 and the one good deer on Ration 5 indicates that about two pounds (3600 calories) of high quality food is required daily for a deer weighing 50–60 pounds, 3–4 pounds (6300 calories) for a 100-pound deer, and 5–6 pounds (9,900 calories) for a

150-pound deer. These are in good agreement with the amounts recommended for domestic ruminants by the National Research Council (1950). It should be emphasized that these are not maintenance requirements but are the amounts (air-dry basis) of high quality food that have permitted excellent growth and development. In terms of good quality native deer browse containing a much greater moisture content these weights of food could safely be doubled. Restriction to about one-half this amount of a similar high-quality diet seriously retarded growth and development (Ration 1C).

The evidence is less clear regarding the quantitative requirements for calcium and phosphorus. The subnormal weight gains of deer on Rations 2 (0.09% calcium) and 4 (0.25% phosphorus) when compared to the deer on Rations 3 (0.65% calcium) and 5 (0.59% phosphorus), as shown in Fig. 2 indicate that the requirements for growth are somewhat greater than 0.09 per cent calcium and 0.25 per cent phosphorus. This has been investigated further in the second and third year studies.

The result of supplementation of the diet with Vitamin A and D, inorganic sulfur, and methionine under conditions designed to reveal any beneficial effects, were negative as shown by the growth curves in Figure 2.

ANTLER DEVELOPMENT—FIRST YEAR—Antler growth started about May 1, 1953 in deer on all diets except the low and medium protein and the calcium and phosphorus deficient rations where growth started 2–4 weeks later. A similar time lag was noted at the time of antler maturity when the deer on the complete rations rubbed off most of the velvet by mid-September while this occurred with the deficient deer about two weeks later. The date of antler shedding, (Table 3) ranged from early January in the deficient deer through February and March in the control animals, although quite a large individual variation (presumably genetic) was observed.

Although the developing antlers of several of the deer were injured on the wire fencing and rather wide differences between individuals on the same diets were observed, the data presented in Table 3 demonstrate the dependence of antler growth on adequate nutrition. Barring injury during the growth phase all four of the control deer receiving the complete diet would have developed antlers 12 to 15 inches in length of the main beam, nearly one inch in diameter at the base, and with 6 to 8 points as illustrated by deer 106 (Fig. 3). The calcium and phosphorus supplemented deer (Rations 3 and 5) that were almost equal in body growth and appearance, had antlers measuring only 8 or 9 inches in length with a smaller diameter at the base, and bearing only 2–4 points. One deer on each of the low energy, low calcium, and low phosphorus diets produced antlers about five inches long (Fig. 4) but all other animals on the restricted diets (including the low-protein diet) made very little or no antler growth. In the young growing deer it seems that body growth

FIG. 3. Deer 106: complete ration fed for one year in unlimited amount.

FIG. 4. Deer 105: low energy ration (restricted intake of complete ration) fed for one year.

TABLE 3.—ANTLER DEVELOPMENT ATTAINED—NOVEMBER 1952 TO OCTOBER 1953

Ration Description	Deer No.	Ave. Length Main Beam of Intact Antler	Diameter, One Inch Above Antler Base	Total Points and Tines	Total Weight of Antlers	Density of Antlers	Date Antlers Shed
		inch	inch	no.	gm	gm/cc	
1. Complete.....	106	15	0.9	8	328	1.73	3/10/54
	117**	13**	0.9	7	225	1.71	2/4/54
	120**	—**	0.7	(stubs)	31**	—	2/23/54
	132*	14	0.8	4	155	1.82	3/26/54
1C. Low energy.....	105*	6	0.5	2	39	1.77	3/7/54
	113	1	0.4	(buttons)	—	—	1/9/54
2. Low calcium....	111*	5	0.6	4	37	1.58	2/18/54 to 2/24/54
	139***	1	0.5	(buttons)	—	—	
3. High calcium....	115**	4**	0.7	2	37**	1.46	1/4/54
	122	8	0.7	3	81	1.55	12/31/53to1/10/54
4. Low phosphorus	135*	3	0.4	2	—	—	1/5/54
	137	4	0.4	4	37	1.64	1/5/54 to 1/10/54
5. High phosphorus	109	9	0.7	2	91	1.68	2/20/54
	134***	1	0.5	(buttons)	—	—	2/17/54
6. Low Ca and P...	128	3	0.4	2	—	—	—
	104 (Died, 5/18/53)						
7. Low Ca and P	118*	2	0.3	1	17	1.76	1/14/54
+ Vits. A & D.	126*	2	0.3	1	11	1.71	1/6/54
8. Low protein.....	131	1	0.3	2	—	—	1/15/54
	136	1	0.3	2	—	—	1/5/54
9. Low protein	123	1	0.4	2	—	—	1/5/54
+ sulfate.....	130*	1	0.4	(buttons)	—	—	1/5/54
10. Medium protein	121*		0.4	1	—	—	—
	119 (Died, 12/23/52)						
11. Medium protein	124	1	0.4	2	—	—	1/29/54
+ methionine...	129	1	0.4	2	—	—	1/15/54

*Antler velvet cut or scraped during development.
**Antler bone broken and severe injury to velvet (involving both antlers in deer 120).
***Poor food consumption with frequent supplements.

took precedence over antler development, for only those making excellent body growth developed large antlers.

The shed antlers were collected, weighed, and analyzed, and bone density determined (Table 3). The weights confirm the length and size data discussed above. The density of antler bone in all deer approached that of normal bone (1.7–2.0 gm/cc). The chemical analysis of the shed antlers, showed surprisingly similar compositions regardless of the diets. The X-ray diffraction patterns, determined by Dr. C. D. Jeffries, Department of Agronomy, revealed an impure apatite (calcium phosphate with chloride and fluoride, $Ca_5(F,Cl)P_3O_{12}$) structure in all deer. There were no significant differences between antlers from different deer or between internal and external portions of the same antler.

RESULTS AND DISCUSSION—SECOND YEAR

Two major changes were made in ration assignments during the second year; the first at the start of the period in October 1953 when the preceding year's antler

growth had ceased, and the second in April 1954 before the second cycle of antler growth was about to start.

The first change consisted of the elimination from further study of Rations 9, 10 and 11, and a slight increase in the protein content of Ration 8. Since little benefit had been observed from the sulfate added to Ration 9 and the methionine supplement in Ration 11, the deer on these rations were shifted to Rations 4 and 6 (low phosphorus, and low calcium and phosphorus, respectively on October 1, 1954). Similarly, the surviving deer on Ration 10 (medium protein) was assigned to Ration 2 (low calcium) in order to obtain more information on the calcium and phosphorus requirements.

The second change in ration assignments was designed to yield some information on the physiological lag between the time of improvement in diet and the resulting effect on growth and antler development. For this purpose one deer of each pair was shifted from the restricted and supplemented diets to the complete Ration 1 on April 1, 1954 while the remaining deer of each pair was maintained on the original diet for comparison. The four original deer on Ration 1, however, were continued on this diet as controls. Two new deer that were raised from fawns during the summer of 1953 (143 and 144) were assigned to Rations 1 and 7, respectively, at this time, and Ration 6 was eliminated.

The winter of 1953–54, although not as warm as the preceding year, was unusually mild for this region with minimum temperatures between 0 and 10°F. occurring on only four days. The mean monthly temperatures for December, January, February and March were 34.9, 26.5, 36.2 and 36.2°F. as compared to the normals for these months of 30.0, 27.2, 27.3, and 36.3°F.

During the spring, summer, and fall of 1954, deer 120 and 122 suffered recurrent attacks of severe diarrhea, ate little feed, and lost weight for short periods of time. Bacitracin mixed with the drinking water was an effective remedy, but normally the deer recovered in 1–2 weeks when this was not used.

The restricted deer (receiving Rations 1C, 2, 4, 6, 7 and 8) during the second year were again observed to be about a month delayed in developing their summer and winter coats when compared to the control and supplemented groups. Deer 130 and 134 continued to be poor eaters and were accordingly subnormal in appearance, growth and vigor.

FOOD CONSUMPTION, GROWTH, AND NUTRIENT REQUIREMENTS—SECOND YEAR—The food consumption of the larger deer on the control and supplemented rations started to decrease with the onset of the rutting season in October 1953. The daily intake of air-dry food decreased rapidly from a maximum of about six pounds (Rations 1, 3, and Deer 109 on Ration 5) to about three pounds per day in mid-November at the height of the rutting season (Fig. 5). This resulted in

FIG. 5. Average daily food consumption, second year.

abrupt weight losses of approximately 20 pounds by mid-December (Fig. 6). A less marked effect of the rutting season was observed in deer on Rations 2 (low calcium) and 4 (low phosphorus) where average weight losses of 5 to 10 pounds were observed, while the undernourished deer receiving Rations 1C, 6, 7 and 8 were only slightly affected. In general, the hormone-induced changes of the rutting season—decreased appetite and greatly increased activity—were most marked in the large vigorous deer and were almost absent in the small undernourished animals.

Following the sharp decrease in food consumption and weight during the rutting season, the deer on the complete and supplemented diets recovered somewhat in food consumption during January (3.5 pounds per day) but continued to lose weight slowly to a minimum in late March 1954. At this

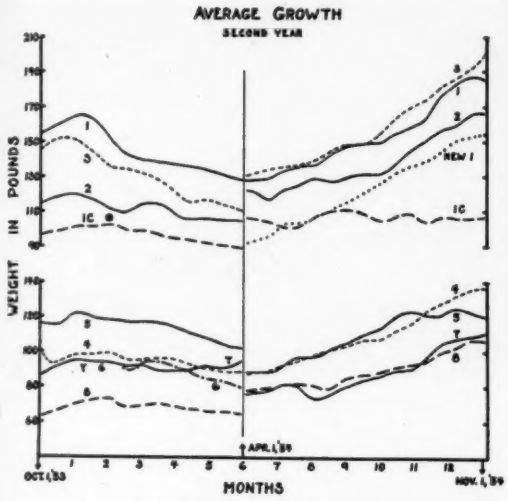

FIG. 6. Average growth, second year.

time their average weight losses ranged from 20 to 42 pounds. The deer on the restricted rations, however, decreased slowly and steadily in food consumption from a daily intake of 3–4 pounds in October to 2–3 pounds by late March and lost only about 10 pounds over the entire period. The reason for this late winter decrease in food consumption and the consequent weight loss is difficult to understand. It occurred in all deer during both winters even though food and water were available in unlimited quantities. The most probable explanation is that it is an inherited adaptation to the winter shortage of food normally experienced by deer in the wild.

On April 1, 1954, one deer of each pair was shifted from the various restricted and supplemented rations to the complete ration to determine the extent of recovery possible in growth and antler development during the spring and summer when food is normally plentiful. Food consumption of these deer increased rapidly to nearly 7 pounds per day in September 1954 and kept pace with those on the complete Ration 1 as did the growth rate (see dotted line designated "New 1" in Fig. 6), but since they started on the average about 40 pounds smaller, the final average weight attained was only 154 pounds compared to 187 pounds for the control group. Body height and length of these deer however did not approach that of the deer receiving the complete ration throughout the study.

The remaining deer of each pair maintained on Rations 2 (low calcium) and 3 (high calcium) also improved greatly in food consumption and growth although the low calcium was not as effective as the high calcium ration. The deer maintained on Rations 4 (low phosphorus), 7 (low calcium and phosphorus) and 8 (low protein) improved slowly in food consumption to about 4.5 pounds per day and in growth to 107–137 pounds by October 1954. The deer maintained on Ration 1C (low energy) throughout the second year (2–3 pounds per day) reached a final weight of 107 pounds.

It is difficult to estimate the average daily maintenance requirement for young-adult male deer in terms of weight of air-dry food or calories because of the extreme seasonal changes in food consumption observed. The data indicate that 3–5 pounds (7,000–9,000 calories) of good quality (air-dry) food is necessary daily for maintenance and weight recovery (following seasonal losses) in adult male white-tailed deer weighing 150–200 pounds. This is about a pound less than the amount needed to support optimal growth in the yearling male weighing 100–150 pounds and is in good agreement with the daily nutrient allowances recommended for domestic ruminants. It should be emphasized that these food requirements are expressed in terms of air-dry food and are equivalent to more than double their weight of good quality native deer browse of much higher moisture content.

ANTLER DEVELOPMENT—SECOND YEAR—Swelling of the pedicels was first noted on several control and supplemented deer on April 15, 1954. By the first of May these had increased to about 1.5 inches in length and growth was visible on all the other deer. Antler growth was extremely rapid during the next two months, slowing somewhat during June and July, and ceasing about August 15, 1954. The antlers hardened and the velvet outer covering was rubbed off about the first of September by several of the deer receiving the complete and supplemented rations. Most of the remaining deer were delayed until the middle or end of September, although quite a large variation was again noted as in the first year.

Measurements of the final antler size attained in terms of length, spread, diameter and total number of points are presented in Table 4. For the second successive year the

TABLE 4.—ANTLER DEVELOPMENT ATTAINED—OCTOBER 1953 TO NOVEMBER 1954

Ration Description	Deer No.	Average Length Main Beam of Antler	Diameter, One Inch Above Antler Base	Total Points and Tines	Spread, Maximum Width	Total Weight of Antlers	Date Antlers Matured
		inch	inch	no.	inch	gm	
1. Complete.....	106	18	1.3	9	16	967	9/2/54
	117	16	1.3	14	14	622	8/29/54
	120	13	1.0	7	14	449	9/5/54
	132	18	1.2	6	14	475	9/14/54
1C. Low energy.....	105	8	0.6	2	8	169	9/30/54
2. Low calcium....	111	12	0.8	8	11	414	9/17/54
3. High calcium ...	115	16	1.0	9	13	544	9/13/54
4. Low phosphorus.	123	14	0.8	3	9	250	9/15/54
	137	12	0.7	6	10	195	9/13/54
5. High phosphorus	134*	12	0.8	4	9	201	9/14/54
7. Low calcium and phosphorus + vitamins A and D	129	7	0.6	2	5	47	
	144**	9	0.5	2	6	****	9/15/54
8. Low protein.....	131	13	0.6	2	6	162	9/16/54
New 1*** complete from April to November 1954.	113	12	0.6	4	10	143	9/7/54
	139*	10	0.8	7	9	223	9/14/54
	122	14	1.0	8	12	430	9/9/54
	130*	12	0.6	6	8	150	9/30/54
	135	12	0.9	8	13	352	9/5/54
	109	15	1.0	6	16	457	9/14/54
	118*	6	0.8	4	7	148	9/4/54
	136	10	0.6	4	9	143	9/2/54
	143**	8	0.8	6	10	177	9/17/54

*One antler injured during development, and poor food consumption with frequent supplements.
**New deer, born summer of 1953.
***One deer of each restricted and supplemented pair transferred to ration 1 on April 1, 1954
****Antlers not recovered when shed.

deer receiving the complete ration made superior antler growth; Deer 117 developed a total of 14 points with a heavy rack about 16 inches long and 14 inches in spread, while Deer 106 and 132 had somewhat longer and larger antlers with 9 and 6 points respectively, and Deer 120 developed a large set of 7-point antlers. These were nearly equaled by Deer 115 on Ration 3 (high calcium), and Deer 109 and 122 that had been shifted from Ration 5 (high phosphorus) and from Ration 3 (high calcium) to Ration 1, respectively, on April 1, 1954. All other deer that had been changed from the restricted rations to the complete ration in April made fairly good antler growth and developed medium-sized branching antlers with 4–8 points. The poorest antler growth was made by deer that were maintained on the deficient Rations 1C (low energy), 7 (low calcium and phosphorus), and 8 (low protein). All of these had thin spikes ranging from 7 to 13 inches in length with a spread of only 6 to 8 inches (Fig. 7).

Deficiencies of energy (less than 4,000 calories daily, calcium and phosphorus combined (0.09 and 0.25%), and protein (4.6–6.6%) seriously limited antler development in these young-adult deer, while single deficiencies of calcium (0.09%) or of phosphorus (0.20%) limited antler development only moderately. Since antler growth again

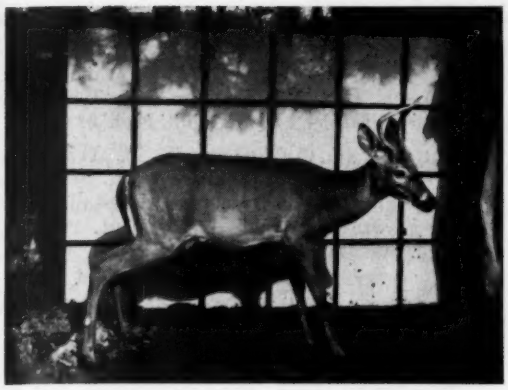

FIG. 7. Deer 131: low protein ration fed for 2 years.

varied with food intake, however, it is difficult to separate this effect from that of the other nutrient deficiencies. A diet-reversal study is now in progress in order to help resolve this and a possible genetic effect.

SUMMARY

Young male fawns were raised chiefly on raw whole milk, calf-starter feed and alfalfa hay until they were about six months old and were then assigned to pens (two animals to a pen). Four deer were fed a ration believed to be nutritively complete in all respects, as positive control. Two more deer were given this same ration but in quantity restricted to about one-half that consumed by the control deer. Two deer were fed a ration complete except for calcium; two others were fed the same ration but supplemented with calcium carbonate. Similarly, other rations were compounded to be deficient in phosphorus, calcium and phosphorus, protein, sulfur, or in sulfur-amino acids. Along with each deficient ration, a companion ration supplemented with the nutrients in question was also fed to 2 deer.

Growth performances indicated a daily requirement of about two pounds (3,600 calories) of good quality, air-dry food for a deer weighing 50–60 pounds, 3–4 pounds (6,300 calories) for a 100-pound deer, and 5–6 pounds (9,900 calories) for a 150-pound deer. The latter is the equivalent of at least 10–12 pounds of good deer browse of higher moisture content. The protein requirement for optimal growth was found to be 13–16 per cent of the ration. Quantitative requirements for calcium and phosphorus were not definitely ascertained, but were in excess of 0.09 per cent calcium and 0.25 per cent phosphorus. Supplements of Vitamins A and D, inorganic sulfur, and methionine were ineffective.

Body growth took precedence over antler development in these young growing deer. Only those on the complete rations, weighing 135–180 pounds, developed large branched antlers, with 6–8 points, about 12–15 inch main beams, and nearly one-inch diameters about an inch above the antler base. A definite improvement in antler development was noted in deer fed calcium and phosphorus supplements as compared to deer on the calcium and phosphorus deficient rations.

During the second year two major changes were made in ration assignments; the first consisted of the elimination from further study of Vitamins A and D, sulfur, and sulfur-amino acids; and the second made in April, 1954, consisted of changing one deer of each experimental pair from the restricted or supplemented diets to the control ration to determine the extent of recovery possible during the spring and summer months.

It was difficult to estimate the average daily maintenance requirement for these young adult male deer in terms of weight of air-dry food or calories because of the extreme seasonal changes in food consumption observed. The 165-pound control animals lost weight rapidly during the rutting season when they consumed only 3 pounds (5,400 calories) per day, lost weight slowly on 3.5 pounds (6,300 calories) during late winter, and then gained weight rapidly to an average of 187 pounds when their daily consumption increased from 4.5 to nearly 7 pounds (8,000 to 12,000 calories) during the spring and summer. This indicates that 4–5 pounds (8,000 calories) of good quality, air-dry food is necessary daily for maintenance and weight recovery (following seasonal losses) in adult white-tailed deer weighing 150–200 pounds. This would amount to a minimum of 8–10 pounds daily of good quality native deer browse with its higher moisture content.

Weight recovery and antler growth in the restricted deer, which were shifted to the complete ration in April, were good, but these deer did not reach the size or have antlers as large as the control and supplemented deer. Deer maintained on the low energy, low calcium and phosphorus, and the low protein rations were stunted in size

and weight to about half that of the control animals (110 pounds), and developed thin spike antlers ranging from 7 to 13 inches in length with a spread of only 6–8 inches. The control and supplemented deer developed large heavy antlers varying in number of points from 6 to 14, with main beam lengths of about 16 inches, main beam diameters, measured about an inch above the base of 1.0–1.3 inches, and maximum spreads of 14 to 16 inches. The calcium deficient ration was again observed to limit antler growth when compared to the companion calcium supplemented diet, but the effect was not as marked as in the other deficiencies.

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GROWTH RATE, SURVIVAL, AND HARVEST OF FINGERLING RAINBOW TROUT PLANTED IN WEBER LAKE, WISCONSIN

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The development of trout fishing in lakes is rapidly gaining in stature as a popular and productive fish-management practice. Many lakes in northern climates are unsuited for the production of warm-water fishes because of low water temperatures and short growing seasons. In these lakes, trout grow well provided some control of the fish population is maintained. This population control has usually consisted in the eradication of the existing fish populations and restocking with trout. Since the trout seldom reproduce in these lakes, the number of trout present is controlled very easily by the rate of stocking. Many of the western states have extensive programs of this kind; the treatment of a single lake in Oregon presumably justified a cost of $150,000.00 (Anon. 1954, 1954a).

This fish-management procedure has permitted the diversion of the natural productivity of a lake from undesirable fishes to the more sought after trout. The rainbow trout (*Salmo gairdneri*) has been the principal species used although other trout have been successfully tried. The present report is a summary of the management of a small, infertile lake in Wisconsin for which a complete record of fishing was maintained for the period 1947 to 1952.

Weber Lake, Vilas County, is in the highland lake district of northern Wisconsin and is rather typical of the small landlocked lakes in this area. It consists of a single depression of 40 acres with a maximum depth of 47 feet. The water is very soft with a total alkalinity of less than 5 ppm.

Prior to 1939 only smallmouth bass (*Micropterus dolomieui*) and yellow perch (*Perca flavescens*) were abundant in Weber Lake. These fishes grew rather slowly compared with the present rate of growth of the rainbow trout. Bennett (1938) reported that smallmouth bass reached a size of 10 inches in three years, based on a rather small collection of 41 specimens. Schneberger (1935) found that yellow perch reached a size of about six inches during their fourth year.

In 1939 a mixed planting of several other warm-water fishes successfully introduced bluegills (*Lepomis macrochirus*), rock bass (*Ambloplites rupestris*), pumpkinseeds (*Lepomis gibbosus*), green sunfish (*Lepomis cyanellus*), largemouth bass (*Micropterus salmoides*), and white suckers (*Catostomus commersonni*) into the lake. This planting was apparently soon recognized as a mistake for the lake was treated with rotenone in 1942 to eradicate the existing fish population. Observations made during the next two years indicated that only central mudminnows (*Umbra limi*) were still present, either by surviving the rotenone treatment or by reintroduction.

Rainbow trout were first introduced in 1945 and annual plantings of this species were subsequently made. In addition, redbellied dace (*Chrosomus eos*) and fathead minnows (*Pimephales promelas*) were introduced in October 1946 to furnish the trout with a forage fish.

Subsequent to the rotenone treatment, Weber Lake was first opened to angling in the spring of 1947. Fishermen were required to obtain a daily free permit and to submit their catch to a census clerk for examination. This requirement yielded an accurate account of the number of fish caught from each of the annual plantings, since scale samples made possible the age determination of all the fish caught by anglers.

Rainbow trout fingerlings were stocked each year beginning in 1945 at densities varying from 100 to 250 trout per acre (Table 1). The average size of the fish in these annual plantings ranged from 1.2 inches to 3.6 inches in total length. The size of the fish was largely dependent upon the time of planting, with the larger fish being stocked during September and October and the small fish as early as May. The fish were stocked at different times, sizes, and densities in order to determine the best way to manage a lake of this kind.

TABLE 1.—RECORDED CAPTURE BY ANGLERS OF FINGERLING TROUT PLANTED IN WEBER LALE

Item	Date of Planting					
	June 30 1945	Sept. 17 1946	May 7 1947	Oct. 15 1948	May 26 1949	Sept. 8 1950
Total number of trout planted	4,000	4,000	6,000	8,000	10,000	10,000
Number of trout planted per acre	100	100	150	200	250	250
Total pounds of trout planted	11	68	26	136	11	148
Average size of trout planted (inches)	2.0	3.6	2.3	3.6	1.2	3.1
Trout caught by anglers in: 1947	54	24	...	...	...	...
1948	10	187	...	...	...	...
1949	3	24	5	370	...	...
1950	1	1	13	82	33	...
1951	...	...	...	14	2	1,637
1952	...	...	1	1	1	189
Total trout caught from individual plantings	68	236	19	467	36	1,826
Total weight of trout caught (pounds)	67	463	58	443	34	682
Percentage of plantings caught by anglers	1.7	5.9	0.3	5.8	0.4	18.3

Fishing pressure was rather uniform on Weber Lake during the period from 1947 through 1952 except for the first year of the census. It ranged from 74 to 226 hours per acre, an intense use compared with other lakes in the vicinity (Table 2). The rate of angling success was poor but the large average size of the fish (13.6 inches) was responsible for the continued popularity of the lake. The total annual production to anglers ranged from 2.2 to 12.3 pounds of rainbow trout per acre and averaged 7.4 pounds per acre. This is considerably better than the yield of brook trout from selected lakes of similar size in New Brunswick reported by Smith (1952), where anglers harvested 0.58

TABLE 2.—CREEL CENSUS DATA FOR WEBER LAKE FOR THE PERIOD, 1947–1952 INCLUSIVE, BASED ON A COMPLETE CENSUS OF ANGLERS

Item	1947	1948	1949	1950	1951	1952
Total angler days	844	1,360	1,738	1,205	1,937	1,483
Angling hours per acre	74	155	226	147	200	164
Total number of fish caught	78	197	402	130	1,653	199
Total pounds of fish caught	86.2	351.6	344.0	233.8	493.5	261.7
Number of fish caught per 100 hours	2.6	3.2	4.4	2.4	21.0	3.0
Number of fish caught per acre	2.0	4.9	10.1	3.3	41.3	5.0
Pounds of fish caught per acre	2.2	8.8	8.6	5.8	12.3	6.5
Average length of fish caught (inches)	13.3	16.6	12.1	15.9	9.0	14.8
Average weight of fish caught (pounds)	1.1	1.8	0.9	1.8	0.3	1.2

TABLE 3.—CHANGES IN FISHING REGULATIONS ON WEBER LAKE, 1947–1952

Year	Open Season	Fishing Hours	Daily Limit	Minimum Size Limit (inches)	Bait Restrictions
1947....	May–September 7	½ hour before sunrise to 1 hour after sunset	5	7	Minnows prohibited
1948....	May 15–October 15	.....	..	..	.....
1949....	.....	½ hour before sunrise to 10:00 p.m.	..	..	.....
1952....	May 3–October 15	.....	10	6	Minnows permitted

pounds per acre per year over a seven-year period. Weber Lake production is similar to that of the fishery for Kamloops trout (*Salmo gairdneri kamloops*) in Paul Lake, British Columbia, where a stocking of 200 fry per acre maintains a sport fishery of approximately 10 pounds per acre (Larkin *et al.*, 1950).

There were several changes in fishing regulations during the six-year census period, most of which were of a minor nature. These were intended to permit a wider utilization of the fish population and to increase the recreational possibilities (Table 3).

The additional open season in the fall and the extension of fishing hours into the evening were instituted because fishermen believed that the extended hours and season at times when the surface water was cooler would make fishing more effective. These two changes had little effect on the number of trout creeled although it is believed that the extended hours did help the fly fisherman.

In 1952, the opening date of the fishing season, the bag limit, and the size limit were changed to coincide with the stream fishing regulations. Another change in regulations involved the use of minnows for bait. This prohibition which was in effect during the period from 1947 to 1951 was intended as a safeguard against the introduction of undesirable species of fish. Although stomach analyses indicated that minnows were not the most important food item, fishermen believed that they would be a very effective bait judging from their observations of many large schools of minnows present in the lake. Consequently, the prohibition was relaxed, and the use of minnows for bait was allowed during the 1952 season.

The returns from individual plantings varied considerably; anglers accounted for 0.3 to 18.3 per cent of the total number of the fish planted in different years. The average total return of 6.3 per cent was based on a recorded catch of 2,652 trout resulting from a combined six-year planting of 42,000 (Table 1). This survival to the creel compares favorably with plantings of a similar nature made in California where an average yield of 5.4 per cent was reported by Curtis (1951). Five annual plantings of fingerling brook trout made in Crecy Lake, New Brunswick made during the period 1946–1950 also yielded an average return of 5.4 per cent to anglers' creels, with the returns from individual plantings varying from 0.1 to 19.7 per cent (Smith, 1952).

The superiority as a management practice of planting trout in lakes over stream plantings of either fingerling or catchable-sized fish may be demonstrated by comparing the total pounds of fish produced to anglers with the pounds planted. In Weber Lake 4.4 pounds of rainbow trout were produced to the anglers for each pound of trout planted. Stream plantings of either fingerlings or catchable-sized trout rarely, if ever, produce a total weight to anglers equal to the original weight of the fish planted.

Plantings of trout from 1.2 to 2.3 inches in length yielded very poor returns compared with fish from 3.1 to 3.6 inches, especially when the smaller fish were introduced in the lake at a time when many larger fish were present (Table 1). The returns from the initial planting of 2.0 inch fish made in 1945 no doubt would have been larger had the lake been open to fishing in 1946. In later plantings, yearling fish made up a large proportion of the total returns from plantings at a time when the fish were from 7 to 10 inches long.

The importance of stocking trout in lakes at a time when populations are low and competition is thereby at a minimum is

TABLE 4.—GROWTH OF RAINBOW TROUT PLANTED IN WEBER LAKE. DATA OBTAINED PRINCIPALLY FROM FISH TAKEN BY ANGLING. THE AVERAGE LENGTHS OF THE FISH AT THE TIME THEY WERE STOCKED ARE LISTED IN PARENTHESES

Age of Fish		Average Size of Rainbow Trout From Plantings Made						
years	: months	June 30 1945	Sept. 17 1946	May 7 1947	Oct. 15 1948	May 26 1949	Sept. 8 1950	July 2 1951
0	1	...	...	...	...	...	...	...
	2	...	...	...	...	...	...	...
	3	...	...	...	...	...	...	...
	4	...	...	...	...	...	...	...
	5	...	...	(2.3)	...	(1.2)	...	...
	6	(2.0)	...	...	...	...	...	...
	7	...	...	...	...	...	...	(2.3)
	8	...	...	...	...	...	...	...
	9	...	(3.6)	...	...	...	(3.1)	...
	10	...	4.8	6.6	(3.6)	...	...	...
	11	...	...	8.0	...	...	...	...
1	12	...	...	...	...	...	...	...
	1	...	...	...	...	...	...	...
	2	...	...	...	...	...	...	...
	3	...	...	...	...	9.3	...	...
	4	7.5	...	...	8.0	...	...	8.5
	5	...	7.0	...	9.6	10.4	7.9	8.9
	6	...	10.2	...	10.2	11.5	8.1	10.7
	7	10.6	11.6	...	11.2	11.8	9.1	12.5
	8	...	12.4	...	12.9	13.6	10.7	13.9
	9	...	...	...	12.9	13.6	11.4	13.0
	10	15.2	13.7	...	14.3	...	12.1	...
	11	...	...	...	...	...	...	...
2	12	...	...	...	...	...	...	...
	1	...	...	...	...	...	...	...
	2	...	...	...	...	...	...	...
	3	...	...	...	15.5	...	...	...
	4	...	14.8	...	...	...	13.1	...
	5	17.3	15.4	14.9	16.3	17.3	13.6	...
	6	17.8	16.1	18.3	16.3	...	14.4	...
	7	18.3	16.5	18.3	17.1	...	15.6	...
	8	18.4	17.3	18.3	17.8	...	17.0	...
	9	...	17.5	18.5	17.8	...	17.4	...
	10	19.0	17.9	...	...	...	17.4	...
	11	...	...	...	...	...	...	...
3	12	...	...	...	...	...	...	...
	1	...	...	...	...	...	...	...
	2	...	...	...	...	...	...	...
	3	...	...	...	...	...	...	...
	4	19.3	18.6	...	...	...	...	...
	5	19.6	19.0	...	21.8	...	...	...
	6	19.5	21.0	...	18.4	...	...	...
	7	...	20.9	19.8	22.9	...	...	...
	8	...	21.8	20.4	20.8	...	...	...
	9	21.1	21.3	19.5	25.0	24.3	...	...
	10	...	...	...	25.0	...	...	...
	11	...	...	...	...	...	...	...
4	12	...	...	...	...	...	...	...
	1	...	...	...	...	...	...	...
	2	...	...	...	...	...	...	...
	3	...	...	...	...	...	...	...
	4	...	...	...	...	...	...	...
	5	21.0	...	23.4	23.7	...	...	...

TABLE 4—(*continued*)

Age of Fish years : months	Average Size of Rainbow Trout From Plantings Made						
	June 30 1945	Sept. 17 1946	May 7 1947	Oct. 15 1948	May 26 1949	Sept. 8 1950	July 2 1951
6	...	...	...	...	...	...	...
7	...	...	...	...	...	...	...
8	...	...	...	...	...	...	...
9	...	22.8	...	...	...	...	...
10	...	...	...	...	...	...	...
11	...	...	...	...	...	...	...
5 12	...	...	...	...	...	...	...
1	...	...	...	...	...	...	...
2	...	...	...	...	...	...	...
3	...	...	...	...	...	...	...
4	...	...	...	...	...	...	...
5	23.2	...	24.6	...	...	...	...

attested to by the Weber Lake experiments. This is especially true when very small fingerlings are involved. Estimates of the trout population were not made during the study period but good or poor survival of individual plantings may be inferred by their total contribution to the catch during subsequent years. Thus it is seen that a planting of 4,000 rainbows which averaged 3.6 inches in length made in September 1946 were quite successful in competing with the survivors of the initial 1945 planting which also was quite successful. However, the 1947 planting of 6,000 rainbows 2.3 inches long and the 1949 planting of 10,000 rainbows 1.2 inches long were almost complete failures. Both of these latter plantings were made when the apparent survival of the 1946 and 1948 plantings was high (Table 1).

Another planting of 10,000 rainbows 2.0 inches long made in July of 1951 was almost a complete failure inasmuch as fewer than 25 fish were recorded captured by anglers. This planting was made at a time when the survival of the 1950 planting of 10,000 rainbows 3.1 inches long was apparently exceptional.

The growth of the different plantings of rainbow trout in Weber Lake was determined largely from angler-caught specimens. Additional data were obtained sporadically during the closed season by trap nets or gill nets. The different plantings were not distinctively marked, but age determinations from scales were used to assign individual fish to the planting from which they originated.

A very few of the trout planted in Weber Lake lived to be five years old, and fish in their 2nd and 3rd years of life dominated the catch (Table 1). The largest trout caught was 25.0 inches in length and the average size of fish in the catch was approximately 14 inches. Despite the large variation in stocking density and the size of the trout at planting, the growth of the different trout plantings was similar (Table 4). This might be interpreted to indicate that the initial survival from plantings was considerably less than the carrying capacity of the lake. The rather good average growth increments approximating five inches each year supports this view.

The exceptional survival of the planting of 10,000 rainbows 3.1 inches in length made in September 1950 was accompanied by a poorer rate of growth. Trout from this planting during their second and third growing seasons were consistently one to two inches shorter than trout of similar age from the other plantings.

During any one year, the growth rate was most rapid during the period from April to October. Some growth apparently occurred during the remaining winter period although few data are available to demonstrate this (Figure 1). Growth in length was very rapid during the second and third growing seasons but declined noticeably during the last three seasons from which measurements were obtained. The two largest fish captured attained 25 inches in length during September and October of their fourth year of life.

Stomach samples were obtained from nearly all of the rainbow trout caught by anglers during the six-year period, 1947–

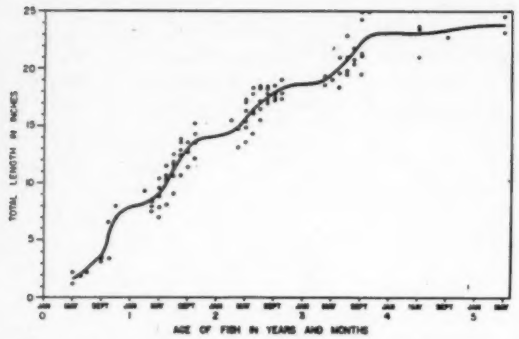

FIG. 1. Seasonal growth of rainbow trout in Weber Lake determined from angler-caught specimens. Open circles indicate size of trout when planted. Closed circles represent average size of all trout taken during a month from a particular planting. Line fitted by a moving average.

1952. In 1951, due to the large catch of fish from one age group, approximately 25 per cent of these fish were sampled. For the six fishing seasons, a total of 1,314 stomachs were collected and the contents examined.

Stomach contents of the trout were analyzed on a qualitative basis only to obtain the relative frequency of which particular food items occurred in the stomachs (Table 5). Larvae of caddisflies, burrowing mayflies and midges were consistently important items of the trout diet. Minnows and cladocerans were also taken in abundance in some years. Only one of the 1,314 stomachs analyzed contained a small trout.

TABLE 5.—ANALYSIS OF STOMACH CONTENTS OF RAINBOW TROUT FROM WEBER LAKE DURING THE PERIOD, 1947–1952. TROUT WERE CAUGHT BY HOOK AND LINE DURING THE OPEN SEASON FOR ANGLING

Food item eaten	Percentage of total stomachs in which various organisms occurred for the years:					
	1947	1948	1949	1950	1951	1952
Cladocera	42	13	28	1	11	12
Gammarus	12	16	13	0	1	0
Ephemeroptera	1	40	23	48	40	28
Odonata	3	12	2	2	3	5
Notonectidae	0	26	3	8	15	3
Sialis	0	17	13	12	4	5
Trichoptera	52	53	19	13	24	38
Gyrinidae	19	12	4	11	3	3
Tendipedidae	30	24	29	41	46	25
Chaoborus	6	5	0	0	0	0
Minnows	6	23	31	65	16	35
Rainbow trout	0	0	0	0	0	1
Frog	0	1	0	0	0	0
Miscellaneous debris	13	21	3	16	3	32
Total stomachs examined	75	175	394	128	435	107
Number of empty stomachs	5	10	43	3	16	6

The importance of minnows in the diet of rainbow trout was investigated because of the prevalent opinion that a forage fish was necessary for continued good growth. In Weber Lake, minnows were very abundant in the stomachs of trout taken in some years and were a minor item in the diet in other years. There were indications also that minnows were taken more frequently by the larger trout. However, the excellent growth exhibited by the trout during 1947 which were feeding to only a limited extent on minnows indicates that minnows are not required for good growth. In 1951, minnows were removed from the lake at the rate of 14 pounds per acre with little apparent effect in reducing the large population of minnows present. This removal of minnows also had at least no detrimental effect on the growth or production of trout since during that year anglers harvested the largest total weight of trout during the six-year period. Trout of all sizes in Weber Lake utilized plankton crustaceans and small invertebrates readily as food. Plankton crustacea were also found to be the dominant food items eaten by rainbow trout in several bog lakes during the major part of the period at which trout were growing the fastest (Johnson and Hasler, 1954).

For this reason it seems probable that minnows are more detrimental to the survival of trout through competition for food than they are beneficial in furnishing forage for the larger trout.

The over-all value of minnows in lakes as forage for the Kamloops trout has also been seriously questioned by Larkin and Smith (1954) because of the direct competition for food between the minnows and small trout.

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SHRUB LESPEDEZA AS A QUAIL MANAGEMENT PLANT IN SOUTHEASTERN VIRGINIA

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Lespedeza bicolor and related species of shrub lespedeza have been widely recommended (Davison 1949) as quail management plants for the southeast. This plant has been widely used in most southeastern states (Pierce 1951) and in recent years a considerable amount of attention has been given to improvement of the strains more suited to a wider area (Davison 1945). From 1948 through 1953, Virginia has distributed 6,926,775 plants and 16,851 pounds of bicolor seed to cooperating farmers. This represents an estimated cost of at least $38,000 for materials alone.

As far as can be determined, very little published information is available regarding the increase of a quail population on agricultural lands due to the planting of bicolor as a source of food for quail. Davison (1949) does present data on the increase which he has observed on quail preserves. In Virginia, the production and distribution of bicolor has constituted a major portion of the farm game program; therefore, it seemed desirable to investigate the responses of the quail populations present on farms following the planting of bicolor.

[1] The author wishes to acknowledge the assistance of Dr. Henry S. Mosby with preparation of the manuscript and of Dr. Vincent Schultz with the statistical analyses.

The farms utilized in this investigation were selected objectively under the following criteria: (1) of sufficient size to permit the planting of at least one acre of bicolor in areas on the farm that, according to proper land-use, were best adapted for such plantings, *i.e.* without hindrance to normal farming operations; (2) crops grown on the farm were typical of the county; (3) the farm was operated as a full-time agricultural endeavor, *i.e.* not as a game preserve or as a part-time venture; (4) the farmer would agree to plant the bicolor strips in conformity with good farm land-use practices as recommended by the local technician of the Soil Conservation Service and the Game Biologist; and (5) the owner would protect the plantings from fire and grazing, and would permit the Game Biologist to census the farm annually for quail for six years. Fifteen farms were selected, one in each of the following southeastern Virginia counties: Amelia, Brunswick, Dinwiddie, Greensville, Isle of Wight, Lunenburg, Mecklenburg, Nansemond, Norfolk, Nottoway, Prince George, Princess Anne, Southampton, Surry and Sussex.

The fifteen farms were mapped and a quail census made in the fall of 1948. In the spring of 1949, bicolor borders were planted as nearly as possible according to the recommendations of Davison (1948). Each plant-

ing was made with seedlings and was 15 feet wide and at least 400 feet in length, and was fertilized with 2-12-12 fertilizer at the rate of 800 pounds per acre. A total of one acre of bicolor plantings, and an average of six borderstrips per farm (ranging from four to eight borders) were planted. One farmer, due to a misunderstanding, plowed up his bicolor plantings in 1951; therefore, records on this farm were not utilized. Thus, the investigation includes records on 14 farms, with 79 field borders totalling approximately 13.5 acres.

The writer assisted in the planting of a majority of the bicolor field borders on the demonstration farms. As is typical throughout most of Virginia and elsewhere (Marshall 1953) practically no maintenance (cultivation, cutting, or fertilization) was given these borders after they were installed. A majority of the plantings would be rated as superior (Rating of "A") under the system proposed by Shaffer (1953).

This experiment was designed with the assumption that if bicolor plantings were properly made under a good land-use plan, they should result in a measurable increase in quail populations on planted farms if they were to be accepted as a quail management tool. The experimental design should have included a number of untreated farms. However, after censusing the quail on the planted farms it became evident that, due to lack of time, this would be impossible. Approximately 150 man-hours and some 300 dog-hours were spent afield for each annual census, not including travel time which in most cases was more than that involved in censusing. Therefore, in order to measure the general trends in the quail population of the region for comparative purposes, ten outstanding quail hunters in each of the 15 counties were requested to supply data on their hunting success during each of the five years, 1949–53. It was impossible to get sufficient cooperators in two of the 15 counties, and about 30 per cent returns were received from the remaining 13 counties for the five-year period. From the data received from these hunters which included hours hunted, coveys located, quail killed, sex of the quail bagged (wings were collected during the first two weeks of the hunting season) it is believed that a reasonable measure of the quail population, characteristics, and trends for the region was secured.

For an annual census of the demonstration farms approximately one man-hour was spent per 100 acres (one-half cleared land) each of five different days during the fall, usually with two well trained shooting dogs. Thus, five man-hours and ten dog-hours were devoted to the annual census of 100 acres. On each trip to a farm a separate mimeographed map was used. The date, time, names of dogs, location, number and direction of flight of all coveys located was recorded. Upon completion of the five census trips, a summary census map was made indicating the estimated number of coveys on each farm. It is not claimed that this was a perfect census, but it is believed that the average bird hunter would not locate any more, and probably not as many quail if he were to hunt any one of the farms during the season.

It has been indicated by Stoddard (1931, pp. 347) that the records of quail seen and killed afield "will be of inestimable value in judging both the trend of quail populations and the causes of abundance and scarcity." Bennitt (1951) indicates in Missouri that the number of coveys flushed per unit of time is "significantly" related to hunting success. Therefore, the records of 10,082.8 hours of hunting in southeastern Virginia are used to evaluate trends in the quail population for the period 1949–53.

For the period studied, apparently no great change in the ratio of juvenile to adult quail was observed, the average percentage of juveniles for the five years 1949–53 being 81.6 per cent as compared to 81.9 per cent juveniles from Missouri for the period 1939–48 (Bennitt 1951, pp. 34).

The average number of coveys flushed by hunters in Missouri (Bennitt 1951) was .749 per hour; in southeastern Virginia, .740 coveys were located per hour hunted. The sex ratio and per cent crippling losses appears to be quite similar (Table 1). The apparent difference in hunting success was possibly due to 42.1 per cent of the coveys of quail being located in woods in southeastern Virginia.

Table 3 records the census results on the 14 farms. Total coveys located are plotted on Figure 1. The quail population appeared to make a sharp rise during the second year of censusing (the fall of the year that the bicolor was planted). The next fall there

TABLE 1.—DATA FROM HUNTER RECORD CARDS

Year	Coveys loc. per hr. hunted	Hours hunted	Quail killed per hr. hunted	Males per 100 females	Per cent shot and lost
1949	.81	890	.92	112.2	12.9
1950	.72	1,742.5	.98	115.0	11.2
1951	.82	2,411.3	.99	114.7	11.0
1952	.72	2,699.5	.89	108.7	8.7
1953	.68	2,339.5	.89	127.7	9.4
AVERAGE	.74	2,016.6	.93	115.7	10.7
(Bennitt 1951):					
	(1943–48) .749		(1938–48) 1.44	(1938–48) 113.41	(1939–48) 7.5

appeared to be a sharp decline in the quail population, followed by a gradual decline with the exception of a slight rise in 1951. It should be noted that there was no large scale change in the crops or land-use practices on any of the farms studied.

TABLE 2.—DATA FROM COLLECTED WINGS

Year	Wings examined (Petrides & Nestler 1943)	Per cent juvenile
1949	482	89.5
1950	558	80.1
1951	476	81.5
1952	477	78.2
1953	414	78.7
AVERAGE	481	81.6
(Bennitt 1951) (1942–48)	51,243	81.9

Data from the hunter questionnaires are presented in Table 1. The reported coveys located follows a downward trend from 1949 to 1950, then a slight increase in 1951, and then a gradual decline in 1952 and 1953 (Figure 1). Thus the numbers of coveys located by hunters in southeastern Virginia appears to follow the same trends as the censused populations on the demonstration farms in that region.

The proportion of juvenile quail (Table 2) appears to follow a similar trend over the period studied, but for practical purposes remains relatively constant.

The question now arises: Are the quail populations on the farms sampled typical of the southeastern section of Virginia? As the farms were not selected at random and control farms were not included in the sample,

TABLE 3.—CENSUS DATA — BICOLOR LESPEDEZA DEMONSTRATION FARMS, 1948–1953

COUNTY	ACREAGE[1] Cleared	Total	Bicolor Borders '49	53	No. OF QUAIL COVEYS LOCATED BY YEARS 1948	1949	1950	1951	1952	1953
Amelia	110	360	6	6	7	9	7	8	6	4
Brunswick	140	290	5	5	6	11	9	11	7	6
Dinwiddie	63	130	8	9	3	5	3	3	4	4
Greensville	119	339	6	6	4	4	4	4	4	4
Isle of Wight	80	160	5	4	3	3	3	2	2	2
Lunenburg	70	142	8	8	2	3	3	4	4	3
Mecklenburg	100	193	5	4	4	5	5	4	3	3
Nansemond	255	405	4	4	5	5	5	5	6	5
Nottoway	115	265	6	4	2	3	4	3	4	3
Prince George	72	177	6	6	3	4	4	2	2	3
Southampton	190	360	6	6	4	3	1	3	3	4
Surry	110	185	4	4	6	7	5	5	4	4
Sussex	70	142	5	5	2	2	3	4	4	4
Princess Anne	310	515	8	8	5	8	6	7	5	5
	1,804	3,661	82	79	56	72	62	65	58	54

[1] The acreage of the area of the farm which was censused; determined in 1953.

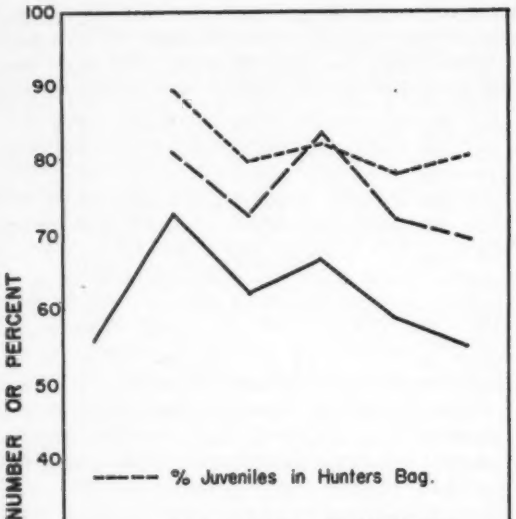

FIG. 1. Hunter and census data as related to year of collection.

this is a proper question. However, in the region as a whole some variables such as per cent juvenile birds in the hunters' bag or number of coveys flushed per 100 hours of hunting effort are believed to be related to the total quail population. If the populations on the censused farms show significant correlation with these variables, we may assume that they are not atypical of the region. Results of tests for significance of a correlation coefficient (Table 4) resulted in a significant correlation between coveys flushed per 100 hours of hunting effort and census results and also between census results and per cent juvenile birds in the hunters' bags.

Since it is apparent that quail populations on the farms planted with bicolor lespedeza showed the same trends over the study period as they did elsewhere in southeastern Virginia it must be concluded that the plantings had no practical benefits in increasing quail populations.

TABLE 4.—RESULTS OF TESTS FOR THE SIGNIFICANCE OF A CORRELATION COEFFICIENT

Correlation Coefficient[1]	D.F.	Value
r_{12}	3	.88*
r_{13}	3	.73
r_{23}	3	.91*

[1] r_{12} = simple correlation between coveys/100hrs. flushed by hunters and census results (total coveys).
r_{13} = simple correlation between coveys/100hrs. flushed by hunters and per cent juveniles in bag.
r_{23} = simple correlation between census results (total coveys) and per cent juveniles in bag.

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EXPERIMENTS ON CAUSES OF DUCK NEST PREDATION [1]

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The observer-approach method of conducting waterfowl nesting studies has been criticized and defended in turn by many individuals concerned with waterfowl research and management. The main objections have been: (1) the tracks and trails made by the observer are apt to lead predators to the nest; (2) nest markers may furnish clues to certain egg-eating birds and mammals which will result in increased predation; (3) activity of the observer at the nest site may lead to subsequent discovery of the nest by crows, magpies, or ravens in the vicinity; (4) increased desertions arise from activity of the field worker; (5) without knowledge of the incidence of renestings, the success recorded in the studies may not provide a true index to actual production; (6) nesting studies are time consuming, and indices to production are more efficiently obtained in other ways (*e.g.*, brood surveys); and (7) certain other sources of error have appeared due to methods used in analyzing data (*e.g.*, the inclusion of small numbers of deserted or destroyed eggs in laying stages, which represent interrupted layings rather than distinct nesting attempts; a general neglect of consideration for the variations in total or average time of observation involved between different samples of nests).

This writing will be concerned briefly with the first four objections listed, and primarily with an additional source of bias not ordinarily recognized; the presence of duck feces on the eggs, nest and vicinity, discharged when the hen was flushed.

Stoddard (1931), Kalmbach (1937), Earl (1950), Lehmann (1946), Bennett (1938) and others considered the possibility that human tracks and trails may lead predators to the nest. Their general opinion is that in settled country this factor may not be overly important and that with adequate care in approaching and leaving nests the observer-induced loss may be held to a minimum.

Predation studies using dummy nests (chicken eggs) were conducted by David McGlauchlin, Howard Woon, Arthur Hughlett, and M. C. Hammond in 1951 on several National Wildlife Refuges in North Dakota and Nebraska. These studies showed no uniform trends to indicate that an increased number of visits lead to increased predation, nor that eggs set out in a cup on a long bamboo pole, not approached closer than 12 to 15 feet, were eaten less frequently than those alongside the observer's trail.

In general it appears that tracks and trails of the observer do not lead to significant increases in waterfowl nest losses to predators if care is used not to form well-defined paths leading up to nests in heavy cover. An exception is the occasional fox or coyote that may accidentally learn that by following the observer's trails food may be more conveniently found than by it's usual searching methods.

Nest markers such as lathes, willows, rags, undoubtedly attract crows and perhaps magpies and ravens, and may aid in their discovery of nests by furnishing unusual objects to attract attention (Bennett, 1938). It is quite apparent from the lack of correlation between the degree of concealment and the success of waterfowl nests (Kalmbach, 1937, 1938; Williams and Marshall, 1938; Hammond, 1940) that avian predators usually locate nests by observing the duck's activities associated with approach and departure. Such clues as nest markers probably aid in locating the exact site, although

[1] The writers gratefully acknowledge the assistance of J. F. Lignon, Oregon State College, for editorial advice. Donald V. Gray and Howard Huenecke, U. S. Fish and Wildlife Service, participated in the 1952 study.

they may not be of particular importance in these respects unless nests have high densities. McGlauchlin concluded that crows, unseen by him, observed his activities in setting out and visiting certain dummy nests within sight of tree groves and later located the eggs without difficulty.

Willow wand nest markers in pastures and the trails of the observer attracted range cattle on study areas in North Dakota and Nebraska. Cattle chewed the markers, pulled them out of the ground, and in one instance followed the tracks made through sandhills and adjoining meadow from nest to marker to nest. Markers in this instance were placed 50 to 100 feet from the nests. It was concluded that nest trampling and disturbance were increased by both the proximity of the markers and the observer's trail.

Except for nests in early laying stages there seems to be no evidence that desertion rates are materially increased by nesting study activities (Kalmbach, 1937; Low, 1940). The desertion rate for diving duck nests is sometimes as high as 50 per cent of the nests regardless of whether they are subjected to nest visits or not. For dabblers the rate seldom exceeded 3 to 5 per cent (including nests in early laying stages) in the Lower Souris Refuge studies, 1936 to 1941.

The fact that waterfowl frequently defecate upon sudden flushing is well established (Bennett, 1938: 50; Hochbaum, 1944: 89; Gross, 1938:396; *et al.*). Speculations have attributed this to purposeful action on the part of the hen to render her eggs distasteful, on one extreme, to the more plausible explanation of simple reflex action. Many workers feel that the fouling of the nests and eggs constitutes a repellant to egg-eating mammals. The studies of the writers, however, strongly suggest that the presence of feces at the nest is at best neutral, and when arising from the intrusion of field workers may lead to an increase in nest losses.

Consider the circumstances in nature: If a mammal flushes a bird from the nest the presence or absence of feces makes no difference—the eggs are already discovered and will be eaten if there is not a repellant effect. In the case of cattle, or buffalo on the plains of past years, a useful end may be gained by the act. Most ungulates, in their grazing, avoid a site splattered with feces.

The senior author's past interest in this and related problems will be reviewed in the following paragraphs. In 1948 he tested a so-called fox repellant (one ounce oil of mustard to one quart of kerosene, with the solution sprayed around the nest). This solution led foxes to the nest, rather than repelling them. Nine of 18 treated nests were destroyed by foxes, two of 18 untreated nests. The ultimate hatch of each series was the same—three successful nests.

Need for control of leafy spurge (*Euphorbia esula L.*) in certain Lower Souris pastures during 1952 prompted location of nests prior to mowing. Other localities were included to increase the sample size. With a rope-tin can drag pulled between two pickup trucks 58 nests were located. The observers walked up to 32 of these, but marked the remaining 26 (usually about alternately) from a distance of an estimated 50 feet, *i.e.*, the nest was not approached until a visit about 10 days later. The rate of predation on the two samples was found to be somewhat higher on the approached series, 56 per cent destroyed per week as compared with 37 per cent for those nests not approached. The histories of the nests were followed until termination when about 40 per cent of the approached series hatched as compared with 30 per cent for those not approached.

It was concluded that (1) flushing plus tracks may have added disproportionately to initial predation on the "approached" series, (2) predation rates on both samples were much higher than could have existed under natural undisturbed conditions, (3) the ultimate fate was probably more dependent upon the scent of nest and eggs defecated upon by the flushed hen than upon tracks or trails made, (4) differences in predation rates of the order indicated may not have been significant.

The Lower Souris blue-winged teal and shoveller nesting data for 1938 were analyzed to learn if a general comparison between (1) nests from which hens had been flushed on a prior visit showed a higher predation rate than (2) nests with the hen absent or not flushed on the prior visit. The former group included an undetermined number of birds which had defecated on the nest (this was not recorded in every instance), the latter group, none.

For 2534 nest-days observation of group (1), the predation rate was 10.8 per cent destroyed per week as compared with 6.7 per cent for 728 nest-days observation of group (2) nests. Projected to full term nests the comparable rates were about 43 per cent destruction for nests with hens flushed and about 27 per cent destruction for nests with hens absent or not flushed on the prior visit.

The writers attempted to obtain more exact data concerning the influence of duck feces upon the fate of nests in 1953. A series of six samples was set up in a variety of topographical and vegetative situations thought to represent a good cross section of probable predator-used locations. Each sample consisted of 20 hen's eggs (half of them scented with fresh duck excrement collected from nests and half of them left unscented) set out singly in various patterns at least six feet on either side of a line of markers. Eggs were arranged in pairs, each pair from 50 to 100 feet apart. The scented egg of each pair was alternated as to direction from the center line or road so that an equal number of scented eggs was on each side (3 stations along roads and 3 in pastures or on idle land). The eggs of each pair were about 12 feet apart in open fields and about 15 to 30 feet apart along road sides. Presumably, if predators followed the observer's trail or the roads, the scented eggs on the upwind side were most vulnerable. The study was completed during the period June 30 to July 18, with visits made to each sample at two- to eight-day intervals.

Significant evidence that the scent of duck feces was a factor in egg loss appeared only at one station (Number 2). The first visit to this line, three days after it was set out, found eight of ten scented eggs missing, but none of the unscented eggs disturbed. Foxes were undoubtedly the predators involved; they had an active den in the vicinity and were using the road as a travel lane.

The final tally of the predation on scented and unscented eggs does not show a significant difference between them (Table 1). The fact that four of the six samples had more of the scented eggs destroyed and the divergence of Sample 2 would suggest that studies of nesting success based upon the observer-approach method might be highly biased, *i.e.*, they may show a rate of predation above that occurring among the nests not studied.

Some of the earlier (1937 and 1938 nesting studies at Lower Souris and recent studies

TABLE 1.—NUMBERS OF SCENTED AND UNSCENTED HEN'S EGGS EATEN BY PREDATORS, WITH NUMBERS EXPECTED UNDER THE 1 : 1 HYPOTHESIS, AND VALUES OF CHI-SQUARE.[2]
TEN SCENTED AND TEN UNSCENTED EGGS IN EACH SAMPLE

Sample Number	Number of eggs destroyed		Expected — Destroyed		Chi-square	
	Scented	Unscented	Scented	Unscented		
1	3	3	3.0	3.0	0.00	
2	10	4	7.0	7.0	2.57	
3	3	2	2.5	2.5	0.20	
4	5	4	4.5	4.5	0.11	
5	1	3	2.0	2.0	1.00	
6	3	2	2.5	2.5	0.20	
Sum of 6 chi-squares					4.08	P 0.67
Total	25	18	21.5	21.5	1.14	P 0.29

INTERACTION

	Degrees of Freedom	Chi-square
Total	6	4.08
Pooled	1	1.14
Interaction	5	2.94
		P Approximately 0.70

[2] From Snedecor, 1946: 189–191.

from several localities) indicated hatching success in the neighborhood of 70 to 80 per cent. Certainly these would warrant the assumption that observer-introduced influences were of minor importance. Later studies (1947 to 1951) frequently showed successful hatchings of only 20 or 30 per cent—the reliability of these samples is to be questioned. It would be expected that, at times, production data from nests might be similar to that from intensive brood surveys. This would result from the occasional balancing of errors in the two samples, or may be only coincidence.

The volume of feces discharged by a duck is many times that used in the dummy nest studies. Both the carrying power and the lasting qualities, hence the amount of predation, would be much greater for nests defecated upon by ducks than for our single egg samples.

It would seem likely that the sense of smell in foxes and coyotes is at least equal to that in the better hunting dogs. Bennett (1938: 122–23) and Sowls (1950: 479) used dogs which were capable of finding nests of both incubating and laying hens and those with hens absent. If the scent of duck feces were added, the susceptibility to predation must be enormously increased in habitat frequented by members of the dog family.

The comparative response between individuals or between mammalian and other species (*e.g.*, snakes) to despoiled duck nests is unknown. It is suspected that most egg-eating animals are attracted by the scent of the feces. A cocker spaniel occasionally used in our work put his nose and mouth into these nests with considerable enthusiasm.

The final conclusion to be drawn from this discussion is that the energies devoted to studies aimed at measuring moderate differences in waterfowl nesting success from year to year, between localities, or between habitats would be more wisely diverted to other lines of endeavor if the method of study involves approaching nests and flushing ducks from them.

Use of such studies may be justified when information is desired about nest density, nest distribution, and nesting cover. Only under special conditions of very low predation or specialized predation types may the observations furnish reliable data on nest losses.

Techniques can be devised to locate nests and record their fate without flushing the hens if the need justifies the effort required. Intensive search for nests following haying operations has been employed. The approximate location of nests can be determined from concealed observation points; the approach being delayed until after they have been terminated.

If the activities of nest location were confined to the early morning or evening a sample could be selected which would include nests only of hens in laying stages or those which had attended the nest a short time before being flushed. These birds would not normally defecate as they flew up. Unattended nests which might be discovered could be included in the sample. Subsequent visits to each nest should be delayed until after the calculated hatch date.

SUMMARY

Duck nesting studies usually provide unreliable information on production due to several types of bias introduced by the observer.

Neglect of consideration for the length of time nests are under observation as compared with the total period they are exposed to predation would lead to a recorded success higher than that actually occurring. This trend is usually, but not necessarily, masked by other factors which cause an erroneously low production estimate. The most important of these are (1) the avian predator's habit of investigating points of activity by the observer, which leads them to find many nests; (2) the interest of range cattle in markers and trails sometimes causes nest loss; (3) the presence of feces, often deposited by the duck at the nest site when she is flushed by the observer, adds appreciably to its chances of later discovery by a mammalian egg-eater. In addition, coyotes and foxes may occasionally learn to find nests by following the observer's trail. These individuals constitute an uncertain, but serious, threat to the success of the field worker's project.

The standard nesting study may be of value to learn details of nest density, distribution, and cover, but only under certain conditions of low or specialized predation will it furnish reliable information about production.

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A SYSTEM FOR EVALUATING COASTAL MARSHES AS DUCK WINTER RANGE

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INTRODUCTION

There is a strong inclination among biologists, sportsmen, and others interested in migratory waterfowl to assume that all coastal marshes are ideal duck habitats. Such an assumption is no nearer being correct than is the assumption by some agriculturalists that all coastal marshes constitute a vast reserve for farmland expansion. Actually, many of these marshes are, in their present condition, almost totally unsuitable for ducks. Superficially, they may appear to be good duck habitat because they are wet lands that support aquatic vegetation. Superficial appearances, however, are poor grounds upon which to plan land use —yet these have commonly been the basis for many decisions regarding marshlands.

Persons who concern themselves with land use planning, including developments for wildlife, need, among other things, practical methods or guides that will aid them in evaluating land as to its suitability for various uses. Several such methods are in common use. One of these is the site classification employed by foresters; another is the land capability classification developed and used by the Soil Conservation Service. Range site and condition classification is used in evaluating range lands for livestock.

A study of the ecology of coastal marshes of the Western Gulf area reveals that, with appropriate adaptations, a system similar to the classification of range conditions for livestock can be used for the evaluation of these marshes as duck habitats. Marshes are essentially grassland associes, and they behave successionally and under disturbance much as do the true grasslands.

EVALUATING RANGELANDS

Present-day range management concepts are based upon a system of range evaluations which embody knowledge of the dynamics of plant succession. Pioneer work which gave rise to that system was done by A. W. Sampson, F. E. Clements, and J. E. Weaver.

Subsequently C. C. Smith, F. G. Renner, B. W. Allred, and E. J. Dyksterhuis contributed to its development. Local refinements and adaptations made by numerous workers in the Soil Conservation Service and other organizations have molded range classification into a fairly simple, yet versatile, tool for range management.

To classify range lands, one needs to be able to (1) identify the plants, (2) understand their successional relationships, (3) determine their relative abundance, (4) recognize the site, (5) be familiar with the normal plant communities that characterize each site, and (6) understand the behavior of important plant species under varying degrees of utilization by livestock.

The division of range condition classes on the basis of percentages of climax vegetation present upon a given range site has been employed by the Soil Conservation Service since 1945. In its use, the degeneration of grasslands as a result of continuous overgrazing is divided into four condition classes, namely, "excellent", "good", "fair", and "poor". Quantitative expression is given to these classes by the present percentage of total covering of higher plant life normal to the site. Qualitative measurement is given in terms of percentage of coverage by original (edaphically climax) vegetation. In the range of 75 to 100 per cent coverage by such vegetation the condition is classified as excellent. With 50 to 75 per cent coverage the condition is good. Fair condition occurs with 25 to 50 per cent coverage, and poor with 0 to 25 per cent.

According to Weaver and Hansen (1941), the reaction of grassland plants to intensive grazing is characterized by three types of behavior: (1) Species of the climax that decrease, (2) species of the climax that increase, but which ultimately decrease under continued intense use, and (3) species that are absent in the climax community but invade the site after disturbance. In range terminology, these groups of plants are called, respectively, "decreasers", "increasers", and "invaders".

After careful ecological observations and measurements have been made in a locality —especially in relict areas or those that have had little disturbance for many years— on each major kind of range site (*e.g.* normal uplands, bottomlands, etc.) the composition percentages for the various categories of vegetation are established. For the category of increasers, "allowable percentages" are set, based upon their normal occurrence in the climax. Other data are assembled to establish safe rates for stocking with livestock. A range condition guide is then developed. An abridged example of such a guide for Gulf Marshes is given in Table 1.

TABLE 1.—TECHNICIANS' GUIDE FOR NATIVE GRASSLAND

Eastern Gulf Coast Marsh

Key Climax Plants by Sites and Others that Invade with Overgrazing

Climax Plants	Site Names		Invading Plants
	Fresh	Salt	
Paille fine	D	0	All annuals
Giant cutgrass	D	0	Seashore paspalum
Savannah panicum	D	0	Alligatorweed
Big cordgrass	0	D	Knotweeds
Smooth cordgrass	0	D	Bigleaf sumpweed
Marshhay cordgrass	0	D	Eastern baccharis
Gulf cordgrass	0	25	Rattlebox
Seashore saltgrass	0	30	Bagpod
Seashore dropseed	0	15	
Olney bulrush	0	D	
Knotroot bristlegrass	0	5	
Needlegrass rush	0	10	
Longtom	10	10	
Common reed	D	D	
Decreasing forbs	D	D	

Range Condition Class	Safe Stocking Rate ac/cow Yearlong		Per cent Climax Vegetation
1. Excellent	3	4	75–100
2. Good	4	6	50–75
3. Fair	6	8	25–50
4. Poor	10	12	0–25

Soil Conservation Service Data.

Legend: 0—Occurs little or none. D—Decreaser. 5–30—Percentage of cover not exceeded in climax condition (*e.g.* "allowable").

In evaluating range condition qualitatively, both the percentage of total plant composition made up of decreasers and the percentage of increasers that is normal for the site under undisturbed conditions are credited. On the debit side are all invaders, plus the percentage of increasers in excess of that normal to the site. Example: A site which normally includes 15 per cent of increasers is examined and found to be composed of 30 per cent decreasers, 35 per cent

increasers, and 35 per cent invaders. This would be tabulated thus:

	Credit	Debit
Decreasers.....	30%	0
Increasers.....	15%	20%
Invaders.....	0	35%
	45%	55%

This range would be considered "Fair," since it falls in the qualitative group of 25–50 per cent climax plants.

EVALUATING DUCK MARSHES

Ducks, unlike range cattle, find their greatest food supply in plants low in the successional scale in the coastal marshes. Thus, the species of plants high on the duck-food scale are low on the cattle-food scale and correspond to range invaders. Few of the subdominant marsh plants—comparable to the range increasers—are of much value to ducks. The marsh dominants (decreasers of the range) are of little value for duck food. Hence, while the method used in evaluating duck habitats is similar to that for evaluating range, the scoring is virtually reversed.

Along the Gulf Coast, and apparently to a considerable extent in Atlantic marshes, there is a great consistency in dominant species for various sites. Penfound and Hathaway (1938) present the most complete study on marsh ecology for the Louisiana coast. Allan (1950) discussed the relationships of various plant communities and successional stages to land use planning along the Gulf Coast. Subsequent work by R. E. Williams of the Soil Conservation Service has led to further knowledge of marsh plant relationships. Briefly, proceeding from the saltiest to the freshest sites, the following plants are dominants:

1. Very salty 4.0–4.5% saline[1]	Smooth cordgrass	(*Spartina alterniflora*)
2. Salty 3.6–4.0% saline	Seashore saltgrass	(*Distichlis spicata*)
3a. Moderately salty (Higher sites) 1.5–3.6% saline	Common Reed	(*Phragmites communis*)
	Big Cordgrass	(*Spartina cynosuroides*)
3b. Moderately salty (Lower sites) 1.5–3.6% saline	Marshhay cordgrass	(*Spartina patens*)
	Seashore saltgrass	(*D. spicata*)
4. Slightly salty to fresh 1.0–1.5% saline	Dominican cattail	(*Typha domingensis*)
	California bulrush	(*Scirpus californicus*)
5. Moderately fresh to fresh 0.5–1.0% saline	Jamaica sawgrass	(*Cladium jamaicense*)
6. Fresh 0.0–0.5% saline	Giant cutgrass	(*Zizaniopsis mileacea*)
7. Fresh 0.0–0.5% saline	Paille fine	(*Panicum hemitomon*)

Important species subdominant in the marshes are:

2. Salty	Bigelow glasswort	(*Salicornia bigelovi*)
3a. Moderately salty (Higher sites)	Saltmarsh bulrush	(*Scirpus robustus*)
	Gulf cordgrass	(*Spartina spartinae*)
3b. Moderately salty (Lower sites)	Saltmarsh bulrush	(*S. robustus*)
	Gulf cordgrass	(*S. spartinae*)
	Olney bulrush	(*Scirpus olneyi*)
	Longtom	(*Paspalum lividum*)
4. Slightly salty to fresh	Delta arrowhead	(*Sagittaria platyphylla*)
	Bulltongue arrowhead	(*Sagittaria lancifolia*)
	Longtom	(*P. lividum*)
	Olney bulrush	(*S. olneyi*)
5. Moderately fresh to fresh	Curltop and other smartweeds	(*Polygonum spp.*)

[1] Percentages of salt in free soil moisture. Based on Penfound and Hathaway (1948).

On the basis of food analyses of 2,101 ducks from the Gulf Coast, Martin and Uhler (1939) list the following plants in order of importance as duck foods.

Wigeongrass	(*Ruppia maritima*)
Smartweed	(*Polygonum*)
Bulrush	(*Scirpus*)
Watershield	(*Brasenia schreberi*)
Waterlily	(*Castalia*)
Wild millet	(*Echinochloa*)
Pondweed	(*Potamogeton*)
Sawgrass	(*Cladium jamaicense*)
Spikerush	(*Eleocharis*)
Beakrush	(*Rynchospora, esp. R. corniculata*)
Panicum	(*Panicum*)
Southern naiad	(*Najas guadalupensis*)
Glasswort	(*Salicornia ambigua*)

A great many species of lesser importance also are listed.

With the above information at hand, we can now construct a habitat evaluation guide (Table 2) similar to a range condition guide. The plants must be divided into three categories—those of high value to ducks; those of moderate value; and those of little or no value.

The first category, or plants to be scored as credits, contains all of the species cited by Martin and Uhler (1939) except sawgrass and bulrushes. These species are assigned to the second category. They rank high as duck

TABLE 2.—GUIDE TO DUCK MARSH EVALUATION
Gulf Marsh Area
Principal Plant Species that Occupy Marsh Sites

Important Food Plants		Secondary Food Plants (Allowable Percentages)		Unimportant Plants
Wigeongrass	Spikerushes	Saltmarsh bulrush	15	Cordgrasses
Smartweeds	Horned beakrush	Jamaica sawgrass	10	Cattails
Watershield	Southern naiad	Arrowheads	10	Common Reed
Waterlilies	Glassworts	California bulrush	5	Seashore saltgrass
Barnyardgrass		Fall panicum	5	Giant cutgrass
Pondweeds		Paspalums	5	Paille fine
		Olney bulrush	5	

DUCK MARSH CONDITION CLASSES

Class	Per cent Col. 1, plus allowable Col. 2
1. Excellent	75–100
2. Good	50–75
3. Fair	25–50
4. Poor	0–25

food, but commonly occur in stands so dense as to be inaccessible to ducks. Local observers have reported that ducks obtain seeds of sawgrass principally at the edges of stands of the plant and where the seeds are washed out into more open spaces.

The second category of plants—species of only moderate value to ducks—include principally the species listed as subdominants, together with sawgrass and bulrushes. Each of these plants is assigned an "allowable percentage". That is, in the evaluation of a habitat, any amounts of these species up to a certain percentage of the total composition are considered credits; amounts in excess of this percentage are considered debits. Allowable percentages must be set arbitrarily at first, and care must be exercised to prevent any probable combination of these percentages from exceeding 50 per cent. The percentages may be established more accurately by careful measurements in relict areas.

The third category of plants contains all species of little or no value to ducks, principally those listed as dominants (Page 249). All are considered to be debits in duck-habitat evaluation.

Duck habitats now may be classified as to their ranking in the following condition classes:

Excellent: 75 to 100% of the vegetation composed of plants in Category I and allowable percentages of Category II.

Good: 50 to 75% of the vegetation in the above categories.

Fair: 25 to 50% of the vegetation in the above categories.

Poor: 0 to 25% of the vegetation in the above categories.

By using the habitat evaluation guide thus developed (Table 2), a marsh may be examined and its quality appraised. For example, a marsh with the following composition has credits in the 25–50% condition class and is, therefore, fair duck habitat:

Species	% Total Composition	% Credit	% Debit
Cattail	30	0	30
Sawgrass	25	10	15
Cal. bulrush	30	5	25
Spikerushes	5	5	0
Fall panicum	5	5	0
Watershield	5	5	0
Total:	100	30	70

Another example is a marsh with credits that fall in the 75–100% class and, therefore, is excellent duck habitat:

Species	% Total Composition	% Credit	% Debit
Wigeongrass	55	55	0
Saltmarsh bulrush	20	15	5
Longtom	15	5	10
Seashore saltgrass	2	0	2
Marshhay cordgrass	8	0	8
	100	75	25

For reconnaissance purposes, ocular estimates can be made after one has had sufficient experience to recognize the important species and determine percentages of plant composition. Since there is a spread of 25 per cent in each condition class, minor inaccuracies in estimating actual percentages are not likely to be of material significance except in border-line instances. The system, however, lends itself to greater accuracy where line transects or quadrats are employed.

The users of this method of evaluation should be aware of several important considerations. It is probable that most wildlife technicians are familiar only with inland marshes. The example given in Table 2 cannot be literally applied to many such marshes—particularly where the nesting of ducks is an essential element in habitat evaluation. Cattail marshes, for example, which rank low in habitat quality in wintering areas, may rank higher in producing areas. It is believed by the author that, with appropriate modifications, his method may be adapted to inland habitats.

It is sometimes desirable to "average out" a marsh where portions of it vary in quality or where two or more (*e.g.* fresh, slightly salty, salty) types of situations occur. Usually, however, greater accuracy will be obtained by evaluating separable parts of the marsh individually.

Unless one is thoroughly familiar with the principal plant species that occur in marshes under study, the collection and identification of the plants is essential.

It is of interest to note that, in the Western Gulf marshes, the factors that result in high quality habitat for ducks are almost directly the reverse of those which provide high range condition for livestock. They also reveal that low successional stages and disturbances are essential to good duck habitats. Furthermore, the plant composition is a fairly good reflection of the amount of open water. A large percentage of watershield or wigeongrass, for example, means that a considerable proportion of the area is in open water.

In developing habitat evaluation guides for other types of situations, *e.g.* Lower Mississippi bottomlands, it has been found that habitats of high quality do not necessarily occur in conjunction with low stages of plant succession.

DISCUSSION

Critics of this system of habitat evaluation have pointed out that food is the only criterion used—it does not reflect such elements as resting areas. The importance of resting areas has never been established as a limiting factor for wintering waterfowl populations. It is obvious, however, that they do need food and that supplies in the winter months are particularly critical. Ducks exhibit no fixed pattern in the selection of resting areas. They often move considerable distances from feeding areas to resting areas. Where undisturbed resting areas are available, as on refuges, ducks frequently do not utilize them continuously.

Another point raised in criticism of the above type of evaluation is that it does not relate in any way to adjoining areas, such as rice fields. Despite an abundance of natural foods on a marsh, actual feeding by ducks may be done principally in ricelands. In Martin and Uhler's list of duck foods for the region, rice ranks eighth. It is likely that, with recent expansions in production, rice now ranks first. The marsh evaluation is not designed for comparative purposes, but solely for the purpose of appraising and planning the specific site under consideration. A preference for rice by ducks does not alter the value of native vegetation in the adjoining marsh. It seems doubtful, moreover, that persons primarily interested in ducks would favor the conversion of a marsh into a rice field.

The evaluation technique is now being employed by the Soil Conservation Service in Louisiana. It serves several functions. Soil conservationists use the habitat evaluation as a tool in land use planning. It can serve as a basis for pointing out waterfowl values on lands that the farmer proposes to drain. It points the way toward measures needed for maintenance or improvement of habitats where the owner elects to use his land for wildlife and where that is the only safe and productive use. It also serves as a record of the actual habitat quality lost through drainage activities. The duck habitat evaluation is only a part of the total evaluations made by soil conservationists in marsh areas. Other appraisals include soil characteristics and land capabilities, use of area by other wildlife, economic feasibility of proposed operations, and feasibility of engineered construction.

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SUMMARY

1. Persons who concern themselves with land use planning in coastal marshlands need methods and guides that will aid them in evaluating land as to its suitabilities for various uses. Some such guides are already in use.

2. Duck habitat is one use for marshes. Since not all marshes are good duck habitat, a system is needed for determining their quality. A system similar to one employed for the classification of range condition for livestock can be developed.

3. Present-day range condition classification is based, in essence, upon successional relationships of plants. Range quality is mainly an expression of how closely grassland vegetation approaches climax conditions. With similar basic ecological information the quality of duck habitats in coastal marshes may be classified. The quality factors used in classifying duck habitats are, in the coastal marshes, inverse to those of range condition.

4. A guide to the evaluation of duck habitat quality has been developed (Table 2), based upon ecological relationships of coastal marsh plants and published data on duck food habits in those marshes.

5. The relative abundance of duck food plants is the only factor upon which the evaluation guide was developed because other habitat characteristics have not been demonstrated to be important limiting factors in the marshes under consideration.

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A STUDY OF WATERFOWL BROODS IN EASTERN MONTANA WITH SPECIAL REFERENCE TO MOVEMENTS AND THE RELATIONSHIP OF RESERVOIR FENCING TO PRODUCTION [1]

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A study of waterfowl production on artificial reservoirs in eastern Montana (Smith, 1953) indicated that the larger reservoirs were superior in brood production. Smith's conclusions were based on monthly visits to all reservoirs. Consequently his data, although indicative of waterfowl and brood use, are not in sufficient detail to permit complete evaluation of the smaller ponds, or the relationships between the small and the large ponds concerning brood use and breeding territories. The present investigation was conducted to help clarify this relationship through an appraisal of brood movements involving marked individuals.

Although Smith concluded that reservoir size had more influence on brood production than vegetative type, he also reported that open-type reservoirs (those with sparse vegetation and subjected to heavy grazing) which constituted 31 per cent of 116 under consideration, produced only 18.9 per cent of 196 broods.

This study was conducted to test the hypothesis that the low brood production was the result of sparse vegetation which in turn was due to livestock grazing. Twelve of the ponds were fenced in 1953 by the Montana State Fish and Game Department to exclude livestock. Changes in the vegetation and brood production were evaluated. The reservoirs are in Carter and McCone Counties. For a description of these areas the reader is referred to Smith (*op. cit.*).

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Methods and Results

Sheep-tight fences were constructed in the summer of 1953 by the Montana State Fish and Game Department, excluding livestock from the upper ends and portions of the drainage areas of six ponds in Carter County and six in McCone County. During the same period a pond of similar location, size and type was selected to serve as an unfenced, paired control for each fenced pond. The average size of the 12 Carter County ponds was 1.32 and that of the 12 McCone County ponds was 2.92 surface acres at high water level. The exclosures on the six Carter and six McCone fenced ponds averaged 1.47 and 2.03 acres, respectively. Intensive vegetative measurements and brood production data were collected during the summers of 1953 and 1954 at the 12 study ponds in each of the two areas. Brood movement data were collected during the spring and summer of 1954 at 44 ponds (about one per square mile) in the Carter County area.

Riparian Vegetation—A total of four 50-foot base lines were randomly selected, two on each side, within the exclosure of each fenced pond. Each base line was marked with two stakes; one stake was located at mud flat-grassland ecotone, the other at the opposite end perpendicular to the waterline. Similar base lines were delimited on each control pond within an area similar to that of the exclosure of the fenced pond with which it was paired. Vegetation density was measured by point-transects consisting of 10

[1] A joint contribution from Montana State College, Agricultural Experiment Station, Project No. MS844, Paper No. 356, Journal Series and the Wildlife Restoration Division, Project W58D, Montana Fish and Game Department.

TABLE 1.—PERCENTAGE DENSITY, SPECIES COMPOSITION, AND AVERAGE HEIGHT OF VEGETATION FOR CARTER COUNTY PONDS, 1953–54

	FENCED PONDS							
	1953				1954			
Major Species	Density (1)	Species Comp. (2)	Height (3)	Ponds (4)	Density (1)	Species Comp. (2)	Height (3)	Ponds (4)
Agropyron smithii	3.28	21.4	6.8	6	7.28	28.4	10.1	6
Hordeum jubatum	2.89	18.9	12.8	4	4.72	18.4	13.5	5
Buchloe dactyloides	2.59	16.9	2.8	5	3.79	14.8	2.2	5
Bouteloua gracilis	0.51	3.3	4.2	3	0.30	1.2	2.4	3
Artemisia tridentata	0.43	2.8	9.8	2	0.51	2.0	9.4	3
Poa cambyi	–	–	–	–	1.45	5.7	8.8	4
Poa pratensis	0.26	1.7	7.4	2	0.73	2.8	14.0	2
Echinochloa crusgalli	0.34	2.2	4.4	4	0.38	1.5	6.2	2
Beckmannia syzigachne	0.34	2.2	23.2	3	0.38	1.5	26.6	3
Distichlis stricta	0.30	2.0	2.9	1	0.21	0.8	4.5	1
Total Major Species	10.94	71.4	7.8	–	19.75	77.1	9.5	–
Total Minor Species	4.38	28.6	–	–	5.87	22.9	–	–
Total Vegetation	15.32	100.0	–	–	25.62	100.0	–	–
Total No. Species	–	34	–	–	–	39	–	–
	CONTROL PONDS							
	1953				1954			
Agropyron smithii	2.92	25.4	7.2	6	4.87	28.7	5.7	6
Artemisia tridentata	1.96	17.1	9.2	3	2.00	11.8	8.6	4
Bouteloua gracilis	1.50	13.1	1.6	4	1.38	8.1	2.1	2
Buchloe dactyloides	0.87	7.6	1.8	2	2.13	12.5	2.0	4
Distichlis stricta	0.50	4.4	3.6	2	1.08	6.4	4.9	2
Hordeum jubatum	0.13	1.1	8.5	2	0.38	2.2	12.0	2
Koeleria cristata	0.17	1.5	2.5	1	0.79	4.7	6.1	4
Stipa viridula	0.28	2.5	8.9	2	0.25	1.5	15.8	3
Total Major Species	8.33	72.7	5.9	–	12.88	75.9	5.5	–
Total Minor Species	3.13	27.3	–	–	4.08	24.1	–	–
Total Vegetation	11.46	100.0	–	–	16.96	100.0	–	–
Total No. Species	–	25	–	–	–	24	–	–

(1) Percentage density (points occupied divided by total points taken multiplied by 100).
(2) Percentage species composition (percentage density of species divided by total percentage density multiplied by 100).
(3) Weighted mean heights in inches.
(4) Number of ponds at which species occurred.

sliding pins placed at one-decimeter intervals on a meter-long "A" frame (Coupland, 1950), and taken perpendicularly at five-foot intervals along each base line. Plants touched at soil surface by a point were recorded as to species and their height measured to nearest one-quarter inch. Because of the importance of *Artemisia tridentata*, data were recorded when a pin touched its branches at any level. One hundred points were taken on each base line; i.e., 400 points per pond, except in some cases where a com-

TABLE 2.—PERCENTAGE DENSITY, SPECIES COMPOSITION, AND AVERAGE HEIGHT OF VEGETATION FOR McCONE COUNTY PONDS, 1953–54

	FENCED PONDS							
	1953				1954			
Major Species	Density (1)	Species Comp. (2)	Height (3)	Ponds (4)	Density (1)	Species Comp. (2)	Height (3)	Ponds (4)
Bouteloua gracilis	6.54	26.0	4.4	5	7.85	22.0	3.4	5
Agropyron smithii	5.66	22.5	8.7	6	7.32	20.5	10.7	6
Hordeum jubatum	1.66	6.6	14.0	2	2.29	6.4	13.5	3
Calamovilfa longifolia	1.41	5.6	5.0	2	0.63	1.8	10.1	5
Distichlis stricta	1.22	4.9	4.4	3	2.68	7.5	8.1	3
Echinochloa crusgalli	1.22	4.9	7.5	2	0.39	1.1	5.6	3
Andropogon scoparius	0.78	3.1	9.5	4	1.17	3.3	14.2	3
Carex filifolia	0.68	2.7	2.8	2	1.80	5.0	4.3	6
Muhlenbergia richardsonis	0.44	1.7	5.6	3	1.37	3.8	5.3	5
Stipa comata	0.39	1.6	6.0	1	0.83	2.3	3.8	4
Total Major Species	20.00	79.6	6.8	–	26.33	73.7	7.9*	–
Total Minor Species	5.12	20.4	–	–	9.41	26.3	–	–
Total Vegetation	25.12	100.0	–	–	35.74	100.0	–	–
Total No. Species	–	44	–	–	–	42	–	–
	CONTROL PONDS							
	1953				1954			
Bouteloua gracilis	6.71	31.3	4.2	5	5.46	24.4	2.1	5
Agropyron smithii	6.17	28.7	7.4	6	5.66	25.4	4.7	6
Distichlis stricta	2.25	10.5	6.0	2	2.96	13.3	5.6	4
Andropogon scoparius	0.96	4.5	3.8	4	0.54	2.4	18.3	2
Stipa comata	0.86	4.0	7.9	3	0.75	3.4	5.2	5
Carex filifolia	0.86	4.0	7.4	4	1.12	5.0	4.3	6
Muhlenbergia richardsonis	0.71	3.3	4.3	4	0.83	3.7	3.3	3
Poa pratensis	0.29	1.4	2.8	1	1.67	7.5	2.0	2
Total Major Species	18.81	87.7	5.7	–	18.99	85.1	3.8**	–
Total Minor Species	2.63	12.3	–	–	3.33	14.9	–	–
Total Vegetation	21.44	100.0	–	–	22.32	100.0	–	–
Total No. Species	–	31	–	–	–	28	–	–

(1) Percentage density (points occupied divided by total points taken multiplied by 100).
(2) Percentage species composition (percentage density of species divided by total percentage density multiplied by 100).
(3) Weighted mean heights in inches.
(4) Number of ponds at which species occurred.
* Two ponds excluded; cattle grazed inside exclosure prior to measurements.
** Two ponds excluded; cattle removed, land plowed fall, 1953.

plete 50-foot base line was prevented by proximity of fence to water. The total number of points taken each year was 4,750 in Carter County, August 30 to September 3 and 4,450 in McCone County, August 12 to 19. (Fences were constructed on McCone County ponds during June and July, and on Carter County ponds in August and September, 1953.) Major vegetation includes those species which were encountered fre-

quently on point-transects, while all others are considered minor species. The results are expressed as per cent density, per cent species composition, and species height (Tables 1 and 2). Plant nomenclature followed Booth (1950), and Booth and Wright (1953).

Carter County ponds: The fenced ponds showed a plant density increase from 15.32 per cent in 1953 to 25.62 per cent in 1954 (Table 1). Five of the 10 major species, *Agropyron smithii, Hordeum jubatum, Poa cambyi, Buchloe dactyloides,* and *Poa pratensis,* contributed largely to the increase. No appreciable change was recorded for *A. tridentata, Echinochloa crusgalli,* and *Beckmannia syzigachne*; whereas *Bouteloua gracilis* and *Distichlis stricta* decreased. *P. cambyi* was recorded in 1954 only.

Control pond data indicate that the total plant density increase 1953 to 1954 was less than for fenced ponds: 11.46 to 16.96. *A. smithii, B. dactyloides, D. stricta, Koeleria cristata,* and *H. jubatum* made up most of this increase. *A. tridentata, B. gracilis,* and *Stipa viridula* showed no appreciable density change.

S. viridula, K. cristata, B. syzigachne, and *E. crusgalli,* important at control ponds, were not encountered as major fenced pond vegetation. *P. pratensis* and *P. cambyi,* important at fenced ponds, were not recorded at control ponds.

The density of minor vegetation for the fenced ponds showed a smaller increase (4.38 to 5.87) 1953 to 1954 than did major vegetation. The number of species increased from 34 to 39. The same trend seems apparent for control ponds with regard to plant density, but the number of species did not increase.

The average height of major species increased 1.7 inches at fenced ponds and decreased 0.4 inch at control ponds 1953 to 1954.

McCone County ponds: Plant density for fenced ponds increased from 25.12 per cent in 1953 to 35.74 per cent in 1954 (Table 2). Five species, *A. smithii, D. stricta, B. gracilis, Carex filifolia,* and *Muhlenbergia richardsonis* contributed largely to the increase; *H. jubatum, Stipa comata,* and *Andropogon scoparius* increased to a lesser degree, while *E. crusgalli* and *Calamovilfa longifolia* decreased.

Total plant density increase at control ponds 1953 to 1954 was only 21.44 to 22.32. A marked increase in density and a decrease in average height were recorded for *P. pratensis* which appeared only at control ponds.

H. jubatum, C. longifolia, and *E. crusgalli,* important at fenced ponds, were not encountered at control ponds. Density increase of minor vegetation for fenced ponds was greater (5.12 to 9.41) than that of major vegetation, but the number of species decreased. A similar trend was indicated for control ponds.

The average height of major species increased 1.1 inches at fenced ponds and decreased 1.9 inches at control ponds 1953 to 1954.

The data for both counties indicate that fencing provided conditions which increased plant density, average height of important species, and modified species composition of riparian vegetation.

EMERGENT VEGETATION—An attempt was made to evaluate the effect of fencing on emergent vegetation. Areas of emergent vegetation in all study ponds were drawn to scale on graph paper as determined by calibrated pacing in both 1953 and 1954. Density measurements followed the method of Low (1945). Culms or stalks per square yard or square foot quadrats, taken at random throughout emergent stands, were counted.

Although emergent vegetation (*Sagittaria cuneata, Alisma Plantago-aquatica, Scirpus validus, Eleocharis* spp. and *Typha latifolia*) did develop at ponds, it was impossible to evaluate the effect of fencing. Unstable water levels and the difference in water holding capacity of the ponds seemed to be limiting factors. Water level measurements, taken at monthly intervals in 1954 with a specially constructed pendulum sight used as an Abney level, show positive correlation between development of emergents and water levels.

Scattered stands of emergent vegetation developed on four (two fenced and two control) Carter County ponds in both 1953 and 1954. Water level drop on these ponds averaged 11 inches from April 15 to July 20, 1954. The remaining four fenced ponds averaged 36 inches water loss for the same period; only traces of emergent vegetation developed. The average water loss was 16 inches for the other four control ponds and

TABLE 3.—NUMBER OF BROODS OBSERVED ON STUDY PONDS OF CARTER AND MCCONE COUNTIES, 1953–54

Brood Species	Carter County				McCone County				Total Broods		
	Fenced		Control		Fenced		Control				
	1953	1954	1953	1954	1953	1954	1953	1954	Fenced	Control	All Ponds
Mallard	3(3)*	3(1)	0	5(1)	2(2)	3(2)	4(1)	1	11(8)	10(2)	21(10)
Pintail	0	0	0	0	2(1)	2(1)	0	0	4(2)	0	4(2)
B. W. Teal	1(1)	1(1)	0	1	0	0	0	0	2(2)	1(0)	3(2)
Baldpate	0	1(1)	0	0	0	0	0	0	1(1)	0	1(1)
Total	4(4)	5(3)	0	6(1)	4(3)	5(3)	4(1)	1	18(13)	11(2)	29(15)
Ponds	6**	6	6	6	6	6	6	6			
	2***	3	0	5	2	3	3	1			

* Figures in parentheses indicate broods assumed to be "resident."
** Number of ponds in each group.
*** Number of ponds with broods.

none developed appreciable amounts of emergent vegetation.

Two of the six McCone County fenced ponds and none of the six control ponds developed moderate amounts of emergent vegetation in 1953. In 1954 the average water level drop on all McCone County study ponds was 34 inches from April 20 to July 13. No appreciable amount of emergent vegetation developed in any study pond in 1954.

Data, from the two weather stations nearest the areas in each county (Albion, Boyes; Circle, Vida), show precipitation from May through August, 1953 was 60 per cent more in Carter County, and 102 per cent more in McCone County, than for the same period in 1954.

BROOD PRODUCTION—Brood census was conducted during morning and evening at about three-week intervals from July 13 to September 15, 1953 and 1954. Numerous supplemental observations were made at various times. In addition to visual inspection, the pond periphery was searched to flush concealed broods. The small number of broods and the sparse emergent vegetation of the ponds simplified individual brood observation and recognition.

Calculation of brood production followed the method of Blankenship, *et al.* (1953), and Gollop and Marshall (1954). All broods were recorded on first census. Those recorded on successive counts, assumed to have been observed on previous counts, were omitted from production figures.

Twenty-nine broods were recorded on all study ponds in 1953 and 1954 (Table 3). Fifteen, observed from two to four times each, indicated a minimum average "residence" period of 24 days for 10 mallard broods, 32 days for two pintail, 15 days for two blue-winged teal, and 44 days for one baldpate brood. Fourteen broods seen only once were considered "transient."

Combined data for both study areas and for both years show 13 resident and five transient broods for fenced ponds, and two residents and nine transients for control ponds. The data for 1953 show seven resident and one transient broods for fenced ponds and one resident and three transients for control ponds; for 1954 there were six residents and four transients for fenced ponds and one resident and six transients for control ponds.

Two of the Carter County fenced ponds accounted for all (four) broods observed in 1953, and four of five broods in 1954. McCone County fenced ponds show the same brood distribution. No broods were seen on any of the Carter County control ponds in 1953, but six were recorded in 1954. Five ponds were represented.

Four broods were noted on McCone County control ponds during 1953; three ponds were represented. Only one brood observation was recorded in 1954.

Considering the combined data of resident

broods, it would appear that the fenced ponds were superior to the unfenced control ponds in brood production, but other factors cannot be ignored. The consistency of brood appearance and residency on only two fenced ponds in each area for both 1953 and 1954, and the erratic appearance of broods on the remainder of the fenced and control ponds, prevent definite conclusions.

BROOD MOVEMENT—Twelve waterfowl nests were located on the study area. Four clutches were color injected by the method of Evans (1951) to color ducklings for subsequent identification; two hatched successfully. Nest hunting was abandoned, and a method of brood capture for direct marking was initiated, because of predation and desertion (75%) of the nests found.

White, yellow, orange or blue airplane dope was daubed on rump, back, or nape (areas of last visible down) of downy ducklings. Scapular feathers of Class II or older ducklings were marked. Seventy-one per cent of all ducklings of 40 broods was captured with the aid of a small net. It was often possible to capture entire Class Ia or Ib broods. In many cases broods marked when Ia or Ib were recaptured and marked again when Class II or older.

The method of brood capture was unique to the small ponds of this area. After a brood was sighted, the assistant maintained visual contact with binoculars while the catcher attempted a concealed approach to the opposite side of the pond. Proper timing of exposure of assistant to brood often resulted in the hen leading brood to opposite shore where it hid in vegetation, or on bare ground. It was important that the assistant maintain visual contact with brood and signal exact hiding position to catcher. The flushing hen sometimes disclosed the precise hiding place, and a careful search usually resulted in netting the brood. Class I broods were often captured close to shore, some in the upper, shallow part of the pond. Class II or older broods sometimes scampered as far as 200 yards away from the pond and were more difficult to catch.

Longevity of marks was directly proportional to duckling age at time of marking and pattern of down-shedding from area marked. Rump, back and scapular marks, appropriately applied, were distinguishable for about 25 days after marking. Under optimum field conditions, colors were readily identified from 100 yards with an 8 x 30 binocular. A 20X spotting scope increased range and efficiency of observation. All broods were categorized to age-classes on basis of plumage development similar to the methods of Gollop and Marshall (*op. cit.*) and Southwick (1953): Class Ia (bright ball of fluff); Class Ib (fading ball of fluff); Class Ic (gawky-downy); Class IIa (first feathers); Class IIb (mostly feathered); Class IIc (last down); Class III (completely feathered, flightless); and Class III+ (capable of flight).

Intensive brood search and subsequent observations were carried on from May 15 to August 5. Duties pertinent to vegetative studies in both counties resulted in loss of contact with many Carter County broods after August 5.

Forty-four ponds, randomly scattered over the 43 square-mile area, were included in brood movement studies. They constituted four vegetative classes, five size groups and five water loss classes.

Vegetative classification (based on extent of emergent and/or riparian vegetation):

Class 1, (9 ponds)—*Typha-Scirpus-Eleocharis* association forms dominant emergent vegetation.

Class 2, (9 ponds)—*Eleocharis - Sagittaria - Alisma* association provides dominant emergent cover.

Class 3, (12 ponds)—*Artemisia-Gramineae* and associated species occur to water's edge; with little or no emergent vegetation.

Class 4, (14 ponds)—Emergent or riparian vegetation is sparse or entirely lacking; usually resulting from water loss, and/or livestock grazing and trampling.

Size groups in surface acres (based on surface area in acres at high water): Group A, (2 ponds) 3.7 to 4.5 acres; Group B, (4 ponds) 1.9 to 2.4; Group C, (8 ponds) 1.3 to 1.8; Group D, (8 ponds) 0.7 to 1.2; Group E, (22 ponds) 0.1 to 0.6 acres.

Percentage surface area loss (based on the per cent difference in surface area due to water loss from June through August): Class a, (10 ponds) 1 to 20 per cent surface area loss; Class b, (11 ponds) 21 to 40 per cent; Class c, (8 ponds) 41 to 60 per cent; Class d, (4 ponds) 61 to 80 per cent; Class e, (11 ponds) 81 to 100 per cent area loss.

Pond water levels may fluctuate depending upon spring runoff, summer precipitation, and ability of ponds to hold water. As summer progresses, the range becomes more arid, and livestock often congregate about ponds. The resultant grazing and trampling often obliterate riparian vegetation and emergent vegetation as it becomes available through water level recession, and change pond classification.

Twelve observations on 9 marked broods (mallard, pintail and blue-winged teal) gave specific information on movements ranging from 0.38 to 1.02 miles (average 0.71) overland. Two to four ponds were occupied by individual broods (Table 4). A general pattern of movements from vegetative Class 4 ponds (bare) to those with emergent vegetation, is indicated. Eight movements were from Class 4; 6 were to Class 2 ponds (with emergent vegetation). Five of 12 movements were from Class 4 to Class 2 ponds, and two broods moved from the same Class 3 pond, after it was changed to a Class 4 by livestock grazing.

Considering pond size, 9 movements were away from small ponds (D or E group). Seven of 12 movements were to larger ponds, two to ponds of the same size group, and three to smaller ponds. The trend of movement appears to be from smaller to larger ponds.

The data indicate that movement trends were in general from ponds with greater to those with less water loss. Six movements were from Classes d and e and 8 were to Class a ponds. Six of 12 movements were to ponds with less water loss, and five were from and to ponds of the same water loss classes. One movement was to a pond with greater water loss.

Numerous observations of 16 marked broods indicated that they remained on their respective ponds between observation dates (Table 5). To evaluate pond usage by these "resident" broods, average broods per pond type (vegetation, size and water loss) were determined by dividing the total number of broods for each type by the total number of ponds of that type on the area. The results show that vegetative Class 2 ponds accounted for 43.7 per cent of the average broods per pond; size Group A, 65.9 per cent; and water loss Classes a and b, 71.4 per cent. This suggests that larger ponds with emergent vegetation, and less water loss provided conditions desirable for broods. These data seemingly substantiate the data regarding broods that were observed to move. Movement trends were to ponds of these types.

An additional 29 miscellaneous broods of all age classes (Table 6) offered further evidence of movement. Fifteen were marked; 14 were not. Ensuing observations within one to three days disclosed three marked and two unmarked broods on ponds where first seen. None of the 29 broods were positively

TABLE 4.—HISTORY OF NINE MARKED BROODS SHOWING MOVEMENT INVOLVING MORE THAN ONE POND, 1954

Brood[1]	Pond Type[2]	Observation Date	Miles Travelled[3]	Days Per Pond
P, Ib, 2	3, D, d	May 31	—	4
Ic, 2	1, D, a	June 8	1.00	5
P, Ib, 3	4, C, b	June 8		
Ib, 2	4, C, b	9	—	6
IIa, 3	2, A, b	18	0.91	14
IIb, 3	2, E, e	July 1	0.66	
IIb, 1	2, E, e	2	—	5
III, 2	3, A, b	17	0.38	
III, 3	3, A, b	18		16
P, Ic, 5	4, E, e	June 20	—	5
IIa, 3	2, C, a	29	0.55	
IIb, 3	2, C, a	July 3		9
P, Ia, 6	2, E, e	July 3	—	8
IIa, 3	3, E, e	29	0.84	19
M, IIa, 2	4, E, e	July 17	—	5
IIb, 1	2, C, a	Aug. 5	0.55	15
M, Ia, 7	3*, E, a	July 1		14
Ib, 6	4*, E, a	10	—	5
Ic, 2	4, D, a	19	1.02	6
IIb, 3	4, E, a	31	0.47	6
M, Ib, 1	3*, E, a	July 1		14
IIa, 7	4*, E, a	10	—	5
IIb, 4	4, D, a	19	1.02	6
T, Ia, 6	4, E, e	July 17	—	3
Ib, 6	2, C, a	22	0.55	
IIa, 6	2, C, a	26		
IIb, 5	2, C, a	Aug. 5		17
T, IIa, 11	4, B, e	July 18		
IIa, 11	4, B, e	21	—	4
IIa, 10	2, C, a	22	0.55	
IIb, 10	2, C, a	26		
IIe, 9	2, C, a	Aug. 5		9

[1] Species, age-class, number in brood; P—pintail, M—mallard, T—blue-winged teal.
[2] See text for explanation.
[3] Straight line distance between ponds.
* Same pond, vegetative class changed from 3 to 4 about July 15.

TABLE 5.—HISTORY OF 16 MARKED BROODS NOT OBSERVED TO MOVE FROM ONE POND TO ANOTHER, 1954

Brood[1]	Pond Type[2]	Observation Date
M, Ia, 7	2, A, b	May 27
Ia, 7		29
Ib, 1		June 3
Ib, 3		9
Ic, 3		11
M, Ia, 1	3, D, d	June 8
Ib, 2		18
M, Ib, 5	1, D, a	June 18
Ib, 1		23
Ic, 4		July 2
M, Ia, 2	4, C, b	June 29
Ib, 4		July 9
M, Ia, 7	3, A, b	June 25
Ia, 7		29
Ic, 6		July 9
IIa, 6		16
IIb, 6		22
IIc, 5		Aug. 3
M, Ib, 3	2, D, a	July 19
IIa, 5		31
IIa, 5		Aug. 3
M, Ib, 3	4, B, c	July 18
Ic, 6		22
B, Ia, 5	2, C, b	July 21
Ia, 2		22
Ib, 2		29
Ic, 2		Aug. 4
IIc, 1		24
III, 1		Sept. 2
P, Ia, 9	2, A, b	June 9
Ia, 4		11
Ic, 3		23
P, IIc, 1	4, C, b	July 4
IIc, 1		9
P, Ia, 8	1, E, b	June 10
Ib, 3		20
IIa, 4		29
P, Ib, 4	3, D, e	June 20
IIa, 3		July 4
IIa, 4		5
P, IIa, 1	3, A, b	June 24
IIb, 1		July 4
IIc, 1		18
III, 1		22
P, IIa, 6	3, D, b	July 22
IIb, 5		30
T, Ia, 8	2, A, b	July 9
Ic, 9		16
IIa, 9		25
IIc, 9		Aug. 2
III+, 9		28
T, Ic, 3	2, C, b	July 21
IIb, 2		29
IIc, 2		Aug. 4

[1] Species, age-class, number in brood; M—mallard, P—pintail, T—blue-winged teal, B—baldpate.
[2] See text for explanation.

identified on succeeding visits. These broods evinced similar distribution among the four vegetative classes. Size Group C ponds accounted for 15 of the 29 broods; water loss Classes a and b had 23 of 29. This suggests that broods moved away from these pond types.

Broods were observed at 30 (68%) of the 44 ponds on the study area. The 14 ponds (32%) without brood observations were 0.6 acre or less in size. All but two had 50 to 100 per cent water loss from June through August.

Brood days per pond may provide better criteria for evaluating pond use than the incomplete histories of the small number of broods available for evaluation. A single observation of a brood movement to a particular pond type may have little significance. Calculated brood days by vegetative classes, size groups, and water loss classes are presented in Table 7. Brood days were calculated from days' lapse between observation dates. In the case of broods known to occupy two or more ponds, one-half of the time lapsed between observation dates was divided between each respective pond unless intervening observations showed otherwise. No allowance was made for time spent before first or after last observation dates, and no brood days were assigned to "miscellaneous" broods. Thus, all figures represent

TABLE 6.—MISCELLANEOUS MARKED AND UNMARKED BROODS THAT APPARENTLY MOVED FROM PONDS WHERE OBSERVED, 1954

Brood[1]		Pond Type[2]	Observation Date
M, Ic,	4*	4, C, b	June 22
M, IIb,	1*	1, D, a	23
M, Ia,	7*	3, E, a	25
M, Ib,	1*	1, C, a	25
M, Ib,	7	4, E, a	25
M, Ia,	4	1, C, b	28
M, Ib,	1*	2, C, a	July 3
M, Ib,	4*	3, D, e	4
M, Ib,	5	3, D, c	16
M, Ia,	3	1, C, a	20
M, Ib,	2	3, B, d	27
M, IIa,	5	3, A, b	Aug. 2
M, IIc,	1	1, C, a	3
M, IIc,	2	1, C, a	3
M, Ib,	1	2, C, b	4
M, III,	2	2, C, a	5
M, III,	1*	4, C, b	5
P, Ia,	5	3, C, e	June 7
P, Ia,	6*	2, C, b	8
P, Ib,	3	3, A, b	23
P, Ia,	3*	4, C, b	29
P, Ia,	7*	4, C, b	30
P, IIc,	5*	4, E, e	July 17
P, Ia,	3*	4, C, b	18
T, Ia,	7*	3, B, d	July 5
T, IIb,	2*	1, E, b	27
S, Ia,	7*	2, A, b	June 23
U, Ib,	7	3, A, b	July 4
U, IIa,	1	3, A, b	20

[1] Species, age-class, number in brood; M—mallard, P—pintail, T—blue-winged teal, S—shoveller, U—unidentified.

[2] See text for explanation.

* Broods that were captured and marked.

TABLE 7.—CALCULATED BROOD DAYS BY VEGETATIVE CLASS, POND SIZE GROUP AND WATER LOSS CLASS, 1954

	Ponds		Brood Days		
Vegetative Class	Number	Per Cent	Total	Average Per Pond	Per Cent Per Pond
1.....	9	20.5	40	4.4	8.6
2.....	9	20.5	241	26.8	52.8
3.....	12	27.2	173	14.4	28.4
4.....	14	31.8	73	5.2	10.2
Total.....	44	100.0	527	—	100.0
Size Group					
A.....	2	4.5	189	94.5	73.7
B.....	4	9.1	9	2.3	1.8
C.....	8	18.2	132	16.5	12.9
D.....	9	20.5	88	9.8	7.6
E.....	21	47.7	109	5.2	4.0
Total.....	44	100.0	527	—	100.0
Water Loss Class					
a.....	10	22.7	142	14.2	27.4
b.....	11	25.0	300	27.3	52.7
c.....	8	18.2	9	1.1	2.1
d.....	4	9.1	15	3.7	7.2
e.....	11	25.0	61	5.5	10.6
Total.....	44	100.0	527	—	100.0

minimum brood days.

The small number of larger ponds for comparison may tend to render data incomparable; however, certain relationships are apparent.

Ponds of vegetative Class 2, size Group A and water loss Classes a and b accounted for the majority of brood days on this area. Pond size appears to have more influence on brood usage than vegetative class. This verifies the findings of Smith (*op. cit.*). The small, permanent and semi-permanent ponds appear to serve an important function as breeding territories. Flightless broods, capable of frequent and extensive overland movements, tend to utilize the larger ponds which contain emergent vegetation.

SUMMARY

1. A study was conducted during the summers of 1953 and 1954 in eastern Montana to evaluate the effect of reservoir fencing on enclosed vegetation and waterfowl brood production.

2. Twelve reservoirs (6 in Carter and 6 in McCone Counties), with sparse vegetation and subjected to livestock grazing, were fenced in 1953. Twelve, of similar location, size and type, were chosen as controls and were not fenced.

3. Density, species composition and height of riparian vegetation within the exclosures and at control ponds were measured by the point-transect method, 1953 and 1954.

4. The data for both counties indicate that plant density of riparian vegetation increased at fenced and control ponds, 1953 to 1954, but the increase was considerably greater at fenced ponds. The height of vegetation increased at fenced ponds only.

5. Unstable water levels, revealed by monthly measurements, seemed to be the limiting factor in establishment and maintenance of emergent vegetation. Thus it was impossible to evaluate the effect of fencing.

6. Brood census on study ponds was conducted, with numerous supplemental observations, at about three-week intervals during 1953 and 1954. Combined data suggested that fenced ponds were superior, but the consistency of brood appearance and "residency" on only two fenced ponds in each area in 1953 and 1954, and the erratic appearance of broods on the remainder of the ponds, prevented definite conclusions regarding the effect of fencing on brood production.

7. A study of brood movements, involving marked individuals of 40 broods (mallard, pintail and blue-winged teal), was conducted during the spring and summer of 1954 at 44 ponds in the Carter County area.

8. Broods were captured with the aid of a small net. Individuals were marked with airplane dope.

9. Twelve observations on nine marked broods gave specific information on movements ranging from 0.38 to 1.02 miles (average 0.71) overland. Two to four ponds were occupied by individual broods. A general trend of movements from bare ponds to those with emergent vegetation, from small to larger ponds, and from ponds with greater to those with less water loss, was indicated.

10. An evaluation of brood days per pond type (vegetation, size, and water loss) of 16 marked "resident" broods, showed that the larger size ponds with emergent vegetation, and less water loss, provided conditions desirable for broods.

11. An additional 29 broods (15 marked, 14 not marked) which were seen once, offered further evidence of movement, mostly from smaller ponds with greater water loss.

12. Pond size appeared to have more influence on brood usage than vegetative class, but ponds with vegetation were utilized more than those without.

13. The small, permanent and semipermanent ponds appeared to serve as breeding territories.

14. Flightless broods were capable of frequent and extensive overland movements and tended to use the larger ponds which contained emergent vegetation.

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A THEORY ON LEAF NESTS BUILT BY GRAY SQUIRRELS ON SENECA STATE FOREST, WEST VIRGINIA

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Although most gray squirrel investigators in this country have taken into consideration the number of leaf nests built in the areas under study, to the writer's knowledge none have undertaken the specific project of determining exactly when leaf nests are built, particularly in relation to other aspects of the life history.

Fitzwater and Frank (1944) stated that poor sanitation, anti-social behavior during the breeding season and lack of den trees and shelter near the food supply might be the primary reasons why squirrels build leaf nests. Several others, notably Seton (1937) and Bailey (1925) are in general accord with these authors.

Most of these writers, however, gave only general information regarding the time when leaf nests are built. Ingles (1947) in his study of the California gray squirrel stated that, "Most of the nest building takes place in the early spring before young are born." D. L. Allen (1942) in his study of the fox squirrel in Michigan stated, "Most nest building occurs during the summer. Some nests, however, are built in late winter and spring before the leaves are out." Brown and Yeager (1945) also indicated that, "Late summer is the period of greatest nest building activity. . . ."

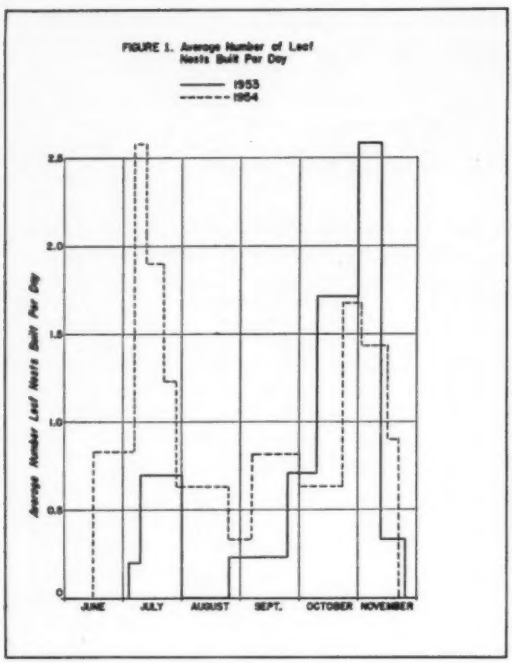
An attempt was made by the author during the summer and fall of 1953 to determine the periods of nest building activity in order to establish the proper time to make leaf nest counts (Table 1). Leaf nests were counted along 24.3 miles of back roads on Seneca State Forest, West Virginia. Measurements were taken from the edge of the woods to the base of the tree containing the leaf nest. It was determined that all of the nests could be seen as far as forty feet from the woods edge. Some of the leaf nests were seen at further distances, but it was believed that beyond the determined limit some nests might be missed. Therefore those nests seen beyond the forty foot limit were cancelled from the data during future counts even though the leaf fall during later months allowed greater visibility.

TABLE 1.—ROADSIDE COUNTS OF LEAF NESTS—SENECA STATE FOREST, WEST VIRGINIA

Dates of Counts	Accumulated Total		Per Cent of Final Total	
	1953	1954	1953	1954
June 15	..	1	..	.7
July 3	8	..	7.2	..
July 5	..	18	..	12.3
July 9	9	..	8.1	..
July 12	..	35	..	24.0
July 20	..	50	..	34.2
July 26	..	57	..	39.0
July 30	24	..	21.6	..
August 9	..	65	..	44.5
August 23	..	73	..	50.0
August 24	24	..	21.6	..
September 4	..	76	..	52.0
September 23	30	..	27.0	..
September 29	..	95	..	65.0
October 6	39	..	35.2	..
October 20	..	108	..	74.0
October 27	74	..	66.7	..
October 28	..	121	..	82.9
November 9	107	..	96.5	..
November 12	..	141	..	96.6
November 18	..	146	..	100.0
November 20	111	..	100.0	..
November 26	..	146	..	100.0

One side of a road was covered at a time with the observer's full attention on locating nests and the driver maintaining a speed of 20 mph. or less. Lines were run as often as possible and special effort was made to run the line every week during known peaks of nest building activity. Leaf nests destroyed by wind or other causes were kept in the count. The average number of nests built per day was determined by dividing the number of new nests observed along the route by the number of days since the last count (Figure 1).

These observations indicated two periods of high nest building activity; one during July, at about the time of the peak of the summer parturition period, and the other in late October, 1953 and early November,



1954. It is believed that building activity was slightly disrupted in October, 1954 because the squirrel season opened on the first day of the month and a heavy hunting pressure was experienced along the roads where the counts were made. In 1953 the hunting pressure was very light.

The second peak of nests did not consist of winter "twig" nests as generally found by investigators in the northern parts of the country, but was composed of a type similar to the summer nests. Twig nests are seldom found in West Virginia. J. M. Allen (1952) found that twig nests were also uncommon in the southern forested areas of Indiana.

One correlation was apparent in both years: the peaks of leaf nest building occurred approximately 18 to 19 weeks after the peaks of the spring and summer parturition periods. When this was noted in 1953 the writer drew three tentative conclusions: (1) the time interval was possibly coincidental, (2) adult females began building nests after their young were fully independent, or (3) the 18- to 19-week-old squirrels were building the majority of the nests.

A statement by D. L. Allen (*op. cit.*) in his study of fox squirrels gave further strength to the latter assumption. He stated, "Many of the "nests" built by fox squirrels are mere handfuls of leaves placed in a crotch. They are often built in late summer and it seems probable that young animals, . . . are responsible for them." While the leaf nests included in the present study were completed nests, the writer felt that the observations were worthy of further investigation.

In 1954 the spring parturition period occurred two weeks earlier than in 1953 and the ensuing leaf nest counts revealed that leaf nest building also started earlier (Figure 1). A close relationship between the rearing success of the spring and summer litters and the extent of leaf nest building was also noted. Assuming that juvenile squirrels 18 weeks old were building the nests, October 6 was selected as a dividing point between the nests built by squirrels born before June 1 (spring juveniles) and those born after June 1 (summer juveniles).

The accumulated total for 1953 in Table 1 shows that 35.2 per cent of the nests were built before October 6 and 64.8 per cent after that date. Checks of juveniles shot during the 1953 hunting seasons which started October 29 indicated that 37.5 per cent were of the spring litter and 62.5 per cent were products of the summer litter.

In 1954 spring den box inspections revealed 17 litters, one more than was found in both the spring and summer inspections of 1953. This indicated that a big spring litter was in prospect and if the previous assumption was true a large number of leaf nests was to be expected in the following summer. This occurred as predicted (Figure 1 and Table 1). An estimated total of 67.8 per cent of the leaf nests found in 1954 were built before October 6 and 32.2 per cent were built between that date and November 18.

A total of 1,438 squirrels were sexed, aged and weighed during the 1954 hunting season on Seneca Forest. Of the 955 juveniles aged, 79.9 per cent were of the spring litter and 20.1 per cent of the summer litter. Although this is in variance with the proportion of leaf nests built by the two groups, it is known that some of the summer juveniles were too young to be "available" to the hunters during the first section of the 1954 hunting season (October 1–16, inclusive). Had the season been delayed 29 days, as in

1953, the proportion of summer juveniles would have been higher and spring juveniles lower. In fact the ratio of spring to summer juveniles killed during the late 1954 season (November 11–27, inclusive) was 66.3 to 33.7 compared to the leaf nest ratio of 67.8 to 32.2 mentioned above. Only 13 per cent of the estimated squirrel population were taken by the hunters and therefore it does not appear that the change in the ratio was due to the hunting take in the October season.

It appears, therefore, that juvenile squirrels approximately 18 weeks of age are the primary builders of leaf nests. Since a minority of females have their young in leaf nests and a few young females of the spring litter are known to have young before the fall hunting season, it is logical to assume that these are the same animals. Incidentally, four tagged, spring juveniles were found to be lactating when they were between 32 to 36 weeks old. Another untagged female collected in February 1954 was estimated to be 30 weeks old when killed. She contained two embryos, six millimeters in diameter.

INTERIOR LEAF NEST COUNTS—Fitzwater and Frank (*op. cit.*) stated, "A census based on the supposition that the animals build only one nest gave reasonable results; hence this conclusion is probably correct in most cases." Goodrum (1940), however, suggested that, "In late fall and early winter one can rely on seeing about one nest to each two squirrels present." Shorton (1951) stated that, "A census of squirrels by counting dreys [1] present on an area could be very misleading."

Comparisons of gray squirrel densities, derived by 1,443 time-area counts in September, and leaf nests counts on 1,510 fifth-acre plots in November and December gave reasonably consistent results in estimates of the number of leaf nests per juvenile squirrel (Table 2). While leaf nests per squirrel, all ages, also gave consistent results, it is believed that this occurred because the juveniles made up the largest proportion of the population (67.9 to 77.6 per cent) in all three years. Leaf nests per juvenile varied only from 1.41 to 1.64 while leaf nests per adult varied from 3.27 nests to 5.03. These data applied only when the forest was considered as a whole. Comparisons made between the time-area counts in September and the leaf nest counts after the middle of November in the nine forest types and stand sizes on the 10,670-acre area indicated that in lower population densities a lower proportion of leaf nests per squirrel is usually found. In areas of high densities the reverse is usually the case. It is believed that the forest type or stand size with the higher densities, possibly because of food supply, might be attractive to independent juvenile squirrels that are moving about. And as a result more squirrels move into the area resulting in more leaf nests per squirrel by November or December when based on the squirrel density as estimated by the time-area counts in September.

Since the number of leaf nests per juvenile squirrel has been reasonably consistent during the past three years and the roadside counts also gave reasonable results of spring and summer rearing success ratios, it appears that population estimates based on leaf nest counts are not valid unless the carryover or number of adults is known or can be reasonably estimated. In designing a sampling scheme for leaf nest counts, the various forest types, acreages, stand classes, aspects, etc. must be considered in the area for which the squirrel population is being estimated. This is necessary in order to compensate for the possible movements before and after leaf nests are built. Late fall population shuffles must be taken into consideration. Roadside leaf nest counts were not indicative of leaf nest densities found in the forest interior, nor did the density of leaf nests appear to be inversely proportionate to the density of available den trees.

SUMMARY AND CONCLUSIONS

1. Peaks of leaf nest building occurred in July and late October or early November, approximately 18 weeks after the peaks of the spring and summer parturition periods.

2. The proportion of leaf nests built in the summer and early winter were almost in the same proportion as the spring and summer rearing success as derived from the kill of juveniles by the hunters. The theory is therefore submitted that juvenile gray squirrels approximately 18 weeks old build the majority of the leaf nests.

3. During the past three years (1952–1954) a total of 1,443 time area counts in

[1] Dreys—English equivalent for leaf nests.

TABLE 2.—COMPARISON OF LEAF NESTS AND GRAY SQUIRREL DENSITIES, SENECA STATE FOREST, WEST VIRGINIA

Year	No. of Plots*	Leaf Nests Per 100 A.	Time-area Counts**	Sq./100 A.***			Leaf Nests Per Sq.		
				Ad.	Jv.	Total	Ad.	Jv.	Total
1952.....	409	47	404	11	32	43	4.27	1.47	1.09
1953.....	516	36	447	11	22	33	3.27	1.64	1.09
1954.....	585	141	592	28	100	128	5.03	1.41	1.10
Total.....	1,510		1,443			Ave.	4.19	1.51	1.09

* Based on fifth-acre plots taken in November and December.
** Based on counts taken primarily in September.
*** Division of age classes are based on kill ratios.

September and 1,510 fifth-acre leaf nest plots in November and December indicated that approximately 1.5 leaf nests per juvenile gray squirrel were built. Age ratios were obtained from a check of 2,179 gray squirrels (94 per cent of the known kill).

4. Since it was found that approximately ten per cent of the tagged, spring juvenile, female squirrels recovered produced litters before they were 32–36 weeks old, it is suggested that litters occasionally found in leaf nests may be products of these spring juveniles.

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EFFECTS OF EXPLOITATION ON A MARTEN POPULATION

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The problem of evaluating the status of animal populations was encountered during a fur resource survey [2] in the Fort Nelson region of northern British Columbia. This paper deals with the possibility of analyzing catch records in order to evaluate the effects of exploitation on a population of marten (*Martes americana actuosa*).

Marten specimens were collected from registered trap lines in an area of about 20,000 square miles during two trapping seasons, 1947–48 and 1948–49. These specimens totaled 127 and 123 in respective seasons and constituted about 16 per cent of the known kill for each year. Additional information useful for the interpretation of kill records was obtained in the field as reported by Quick (1953).

The recent history of fur production in this region suggested that the trapping pressure was not detrimental to the population. Although a high level of fur production continued through at least eight years the gross production data did not provide a means of interpreting the status of the population or the effects of trapping pressure on the fauna. Data obtained from separate trap lines within the region revealed some variations that suggested the possibility of analyzing trapping pressure.

One of the important population characteristics, sex ratio (of the kill), was readily determined. Variations in the sex ratio of the kills made by different trappers demonstrated that the timing of trapping operations resulted in selective sampling of the sexes. This has been reported in preliminary form (Quick, 1953).

Another important population characteristic, age class determination, has not been satisfactorily worked out for the marten but Marshall (1951) has made progress on this subject. The degree of development of the sagittal crest as an age class criterion has been described by Marshall and others. The sagittal crest characteristic was used in this study to classify marten skulls into groups (Table 1). Sagittal crest measurements were made by Kenneth Clayton under the supervision of Dr. W. H. Burt.

TABLE 1.—CLASSIFICATION OF TRAPPED MARTEN BY SAGITTAL CREST LENGTH IN MILLIMETERS

MALES							
Collection	0–10	11–20	21–30	31–40	41–50	51–60	Total
1947–48	7	1	1	18	34	1	62
1948–49	47	0	1	3	15	0	66

FEMALES					
Collection	0–10	11–20	21–30	31–40	Total
1947–48	35	10	10	8	63
1948–49	42	6	3	4	55

There is little basis for a classification of age groups on such characters as total length or weight because the variations of these characters are not sufficiently distinct. Marshall has shown that the plotting of these features tends to indicate a normal curve. This leads to the assumption that age class definition is impractical on the basis of these characters. For this reason these characters will be discussed later only from the standpoint of evidence bearing on an analysis of exploitation.

In the absence of absolute age class characteristics some hypothetical criteria are employed here. As mentioned previously, a continued high level of fur production indicated that the population could sustain trapping pressure. This inferred that it consisted of animals of several age classes.

The literature indicates that marten do not bear young until they are three years old (Asdell, 1946). If a population of marten thrives and produces a sustained yield for more than three years it is reasonable to conclude that the population consists of all age classes between young animals of the current year and their mothers. Thus, the population must have at least as many age

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classes as the sum of the minimum bearing age plus one (representing the young of the year). Therefore a persisting population of marten must consist of at least four age classes. This provides hypothetical criteria with which to examine a collection for the purpose of analyzing the effects of trapping.

One of the limiting factors involved in this approach is the quantity of material available from a given locality representing a given period of time. It has been assumed that the material used in this study has met these requirements.

The application of the age class hypothesis described above to the actual sagittal crest measurements separates the specimens into several groups (Table 1). Although various inferences can be induced by the manner in which the data are grouped the following interpretations were used to analyze the effects of utilization as will be shown in a following section. Inspection of Table 1 shows that a large proportion of female marten trapped either have small sagittal crests or none at all. Known-age specimens examined by others have shown that this feature is indicative of young animals. It seems reasonable to conclude that the specimens with crests in the 0 to 10 mm. class are young of the year. A further examination of these data show fewer specimens in the longer crest classes. This is rather constant in the female specimens for two successive years. It could be inferred that four age classes are represented and that possibly these age classes were roughly indicative of their respective proportions in the wild population at the beginning of the trapping season.

The age group represented by the 11–20 millimeter crest class could be regarded as yearling animals, approximately one and one half years old when killed. These should not be considered part of the breeding population because of immaturity. Another group in a larger crest class, 21–30 millimeters, would represent the youngest breeding age class while the group in the 31–40 millimeter class would be older adults.

A similar classification can be made with the male specimens although the frequency distributions of the "younger" age groups representing two seasons, are more erratic. Only three dominant groups appear among the males. This can be explained by the opinions of some investigators that males develop a crest more rapidly than females. Nevertheless, a distinct group can be discerned in the 0 to 10 mm. crest class which were likely young of the year. The next two classes are too poorly represented to permit age group assignment but the 31 to 40 mm. group shows distinction as an older age class.

In a year-by-year comparison the female specimens demonstrate more constancy in crest class representation than males do. Female specimens show a gradual regression in the frequency with which the older age classes are represented. Male specimens are more erratic. It is not yet clear if this is because of variations in the rate of development or because the population was not adequately represented by this collection.

Assemblage of the specimens into hypothetical age classes permits a comparison of reproductive rates demonstrated by the specimens with those from cage-controlled experiments. Marten litters whelped in captivity vary from one to four young. Asdell and others give a mean of 2.6 young per litter.

The total young of the year of both sexes is shown to be 42 (roughly 30 per cent of the collection). The animals which could conceivably represent the mothers of these young animals number 18 and occur in two sagittal crest classes which might be regarded as young breeding adults and older breeding adults. This grouping indicates a reproductive ratio of one adult female to 2.3 young of the year. It is nearly equal to the mean litter size of 2.6. The differential might be hypothetically regarded as the result of juvenile mortality, "recruitment," or both.

Applying this same procedure to the data representing the next year, shows 89 young of the year and only seven adult females (using the same sagittal crest class limits). The apparent reproductive ratio here is 1 to 12.5 which is clearly excessive according to the literature. It is more than five times greater than the known reproductive rate from cage-controlled experiments. Almost half of these young animals were obtained from E. O. Callison, who exerts exhaustive trapping pressure on his line. As will be explained later, this affects the ratio of the age classes in the kill and accounts for the high proportion of young animals in the 1948 collections. The ratio of young to adults indicated by the 1948 collection is not a valid

appraisal of the character of the marten population in the region as a whole.

Some information was obtained in greater detail from E. O. Callison that is helpful in an attempt to analyze trapping pressure. During 1947–48 Callison made a good catch of 48 marten from his line of about 100 miles in length. Although only a part of his catch was collected as specimens it demonstrated a ratio of one adult female to 3.2 young of the year. This ratio suggests that trapping intensity nearly sampled the respective age groups in the wild population as it approaches the known reproductive ratio. It can be construed to infer that additional trapping pressure would have produced a few more adult females, or, that adult females remained the residual population.

In the second year of the study Callison trapped 52 marten from the same area using identical sets. His entire catch was collected and has been prepared as museum material. The sexes were exactly equally represented and according to saggital crest measurements, the provisional age classes were also exactly divided between the sexes. As shown in Table 1A there were no intermediate age classes but the extremes were well represented in both sexes. These data show a reproductive ratio of one adult female to 6.6 young of the year. It might be suspected that the adult female population was not adequately sampled and that a residual female population still existed in the wild.

TABLE 1A.—CLASSIFICATION OF TRAPPED MARTEN; GROUP BREAK-DOWN OF TABLE 1

	MALES					
Collection	0–10	11–20	21–30	31–40	41–50	51–60
1947–48						
E. Callison*	1	0	0	9	2	0
J. Callison**	0	0	1	5	9	0
1948–49						
E. Callison***	20	0	0	0	6	0
All others	27	0	1	3	9	0
	FEMALES					
Collection	0–10	11–20	21–30	31–40	41–50	
1947–48						
E. Callison*	12	1	1	3	0	
J. Callison**	2	3	7	1	0	
1948–49						
E. Callison***	20	0	2	4	0	
All others	22	6	1	0	0	

* Specimens represent 60% of E. Callison's 1947 catch.
** Specimens represent 43% of J. Callison's 1947 catch.
*** Specimens represent 100% of E. Callison's 1948 catch.

Additional information from this area and about the activities of this trapper permit further speculation. During this study I made the last trip of the trapping season with Callison over his line in order to spring the traps. This trapper's chief concern was whether or not some "fur" yet remained on his line. In the course of four days of travel not one marten track was observed along the trap line although the tracks of other animals were seen. However, excursions back off the line about one mile revealed the presence of marten in areas adjacent to the trap line. When an analysis of the catch for two consecutive years is made with this additional information it begins to appear that the vigorous trapping activity has created a population vacuum by the end of the trapping season. This vacuum can be visualized as a belt equal in width to the average home range of the species. Beyond the belt the habitat was found to be populated with resident animals. These become the parents of a new generation which in the following summer disperse into the vacuum created during the previous trapping season. The parents, already well established, tend to remain in familiar territory.

It appeared that an immigrant population (the catch of 1948–49) invaded the area exploited by Callison in 1947. This new population consisted of mostly young of the year as shown by the catch of 40 young animals to 12 adults. This analysis of the population which indicates a preponderance of young animals agrees with an axiom of demographers that a growing population consists of predominantly young animals (Allee *et al.* 1949). The population removed from this area could be regarded as a "growing" population in the sense that it is composed of immigrant individuals which have not as yet established themselves in the environment.

Older animals which were trapped from this area either had survived a previous trapping season or were itinerants lured into the vacuum created by the removal of other animals. More information on the undisturbed distribution of a population would help to evaluate the effects of exploitation as well as production potential.

E. O. Callison's "exhaustive" catch produced about one marten for each two linear miles of trap line. This catch was sustained

for two consecutive years. Newby's (1954) recent live-trapping studies indicate a resident population with a maximum radius of action of 1.6 miles for males and 0.7 miles for females. His data indicates a minimum foraging area of 0.56 square miles for males and 0.12 for females. This demonstrates a minimum average diameter of range of about 0.6 miles which in other words would permit a distribution of less than two animals per linear mile of habitat. Habitat blanks are common and of course would reduce the pro-rata population distribution either on a linear or an areal basis. Although Callison's catch records are difficult to correlate spatially it seems from this that the removal of one animal per two miles of trap line could be "exhaustive." Actual performance of the traps and post-season track counts on three trap lines strongly indicate that this can occur. The continuation of Newby's work would greatly aid in the evaluation of the effects of exploitation.

Partial catch records were obtained from John Callison who traps a larger area adjacent to E. O. Callison's trap line. Specimens obtained from John Callison represent the catch of the latter quarter of the 1947–48 season. It is shown in Table 1A that more adult animals than young were represented in John Callison's catch. Also, no young males appear in this collection. These data are reciprocal to early season catches which first show a preponderance of males and secondly a preponderance of the younger age classes. In contrast, late season catches produce more females and older age classes.

Collections from the Snake River Indian village as shown in Figure 1 demonstrate a 2 to 1 ratio of males to females. The predominance of heavy or old animals in this case can be attributed to under-utilization which has permitted animals to establish themselves in home ranges and to grow to a large size. Although as later acknowledged, weight is not a good criterion of age class, heavier animals in this collection probably reflect a somewhat older population. Generally speaking Indians do not trap hard for winter fur and it is therefore possible for animals to establish themselves and occupy definite home ranges for some time. Those which survive one or more trapping seasons could conceivably grow to larger size and attain greater weight.

A comparison of weight with the respective sagittal crest class of each specimen shows that the specimens with longer sagittal crests are also heavier animals. This is true of females as well as males. The roughly correlative sagittal crest-weight data obtained from specimens collected along Indian trap lines seems to corroborate the viewpoint that light trapping intensity permits marten to establish home ranges and to grow older and heavier before being caught. Such areas probably produce less fur because the resident animals usurp and defend a large proportion of the habitat. This forces the new generation to search elsewhere for suitable home ranges and because of this the largest single age class of the population is shunted away from the trap line.

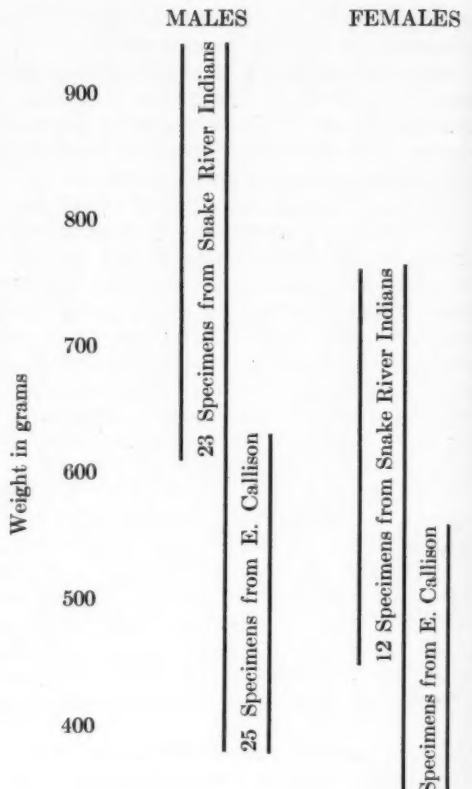

FIG. 1. Comparison of marten weight groups by sex from two areas.

Markley and Bassett (1942) kept weight records of marten raised in captivity. Their weight gain data show ". . . that physical

growth is nearly complete when the kits are three months old." Brassard and Bernard (1939) have also weighed marten raised in captivity and reported the weights of adult animals. These authors found that young marten attain adult weight at three or four months. Newby has found that live weights of individuals vary 100 to 200 grams between repeated live trapping intervals. Fluctuations in weights of individuals might be attributable to cage anxiety. Therefore specimens collected from trappers should be suspected of having lost weight.

Brassard and Bernard have noted "considerable overlapping of weights among large females and small males." There is no statement regarding differences according to age. Specimens collected from the Fort Nelson region were weighed in grams as received from the trappers. These had been pelted but the specimens appeared to be in comparable condition, usually thoroughly frozen. The weights obtained in this manner were tabulated by 100-gram classes for the two seasons of collection. The data demonstrated a normal frequency distribution when plotted but a greater number of specimens occurred in the lighter classes in each sex for each season of collection.

Specimens collected from E. O. Callison were found to be noticeably lighter than collections from other sources. Male marten in the weight class of 600 to 800 grams constituted the lower 60 per cent of all males killed on Indian trap lines. This same weight bracket embraces the upper 44 per cent of Callison's catch of males. Female marten from the area only lightly trapped by Indians exhibited this same relationship to the animals taken from an area repeatedly exploited. As in the case of males the intensively utilized area also produced the lighter female animals. Female specimens in the weight bracket of 550 grams or more constituted the upper 50 per cent of the kill made by Indians whereas the area intensively trapped by Callison did not produce any females above this weight.

These data lead to the conclusion that the area intensively exploited by Callison was completely depleted of marten by the end of the trapping season. Animals which were caught during the following season probably were young animals which had dispersed from areas where they were born that are not traversed by trap lines. This probably explains why the entire catch on this intensely exploited area is lighter in weight than the bulk of the catch from the region as a whole. In areas that are only lightly trapped animals which establish home ranges here might survive two or more years and develop to a larger size.

Although it has been shown by others that marten achieve adult weight early in life the data do not entirely support this view, but favor lighter animals and indicate a differential weight-gain rate between the sexes. It has been stated (Allee *et al.* 1949) that a growing population has a preponderance of young age classes and this might be an explanation of the condition found in the weights of a collection of marten from an intensively exploited area. An influx of new animals would constitute a young and vigorous population with a preponderance of young age classes. This agrees with the analysis of exploitation based on a hypothetical age classification of the kill.

The difficult problem of quantitatively measuring the effects of exploitation still demands a good appraisal of pre-season populations. Lacking this knowledge, only "normal yield" records are available as a datum from which to view the over-all effects of trapping or hunting.

In any species in which the reproductive characteristics are known, a hypothetical rate of increase can be calculated. A hypothetical population can also be described in terms of sex ratio and age classes. These characteristics permit making an estimate of the proportion of young animals of either sex in a population. This might be viewed as the rate of "recruitment" or translated into terms of "normal yield."

Another means of appraising "normal yield" is from catch or kill records. If kill levels are sustained over a period of years within a well defined area it can be assumed that the level of exploitation is not inimical to the population. Such conditions account for mortality without, however, evaluating this factor. This description of production potential is conservative and one cannot know how much more fur could be taken without over-exploiting the population.

These two types of information define the level of a maximum and a minimum yield between which lies an optimum level of utilization. The former value is population-relative and the latter is space-relative.

Inasmuch as the two values are not in the same terms they cannot be used directly as variable factors for evaluating yield. However, these values provide a bracket to which actual area-kill records can be compared for the purpose of determining the level of utilization.

An empirical application of the hypotheses derived from this study to the actual kill or production records would be as follows: a hypothetic marten population includes 30–40 per cent young of the year. This level varies somewhat but if the reproductive rate and the sex ratio remain constant the young-of-the-year age class varies but little in proportion to the total population. This age class cannot be completely exploited if the population is to maintain vigor. Still, the mature breeders are of more immediate value than young since the young must survive three years of the rigors of nature before they will contribute to the population (there is some evidence that marten breed at 15 months and would thus bear young at 24 months). It would then seem ideal to trap all of the young except enough to counter mortality in all age groups. This is a difficult biological phenomenon to evaluate. We are left with only the analysis of the kill and a comparison of this analysis to the hypothetical population structure built up from reproduction characteristics as a means of evaluating utilization.

Approximately 750 marten were actually pelted each year for three consecutive years (1947–1948–1949) in the Fort Nelson region. As previously described the region is laced by some 2,000 to 2,500 miles of registered trap line. However, all of this line is not trapped every year because some trappers alternate operations on sections of their lines. The average catch per linear mile determined directly from some trappers was about one marten per two miles of line. This average is slightly higher than the pro-rated catch for the region. Some animals are killed in traps but never reach the market because they are damaged by birds, squirrels, shrews, and other animals. An average of one marten per three miles of line is a practical description of the production level or "yield." This figure should account for habitat blanks. Using this information as frequency distribution data the pre-season population of the region would be calculated at about 2,200 animals. The annual kill of marten would then represent about a third of the pre-season population which is about equal to the hypothetical increment.

The information derived from this study indicates that this sample of the population is drawn from a "sample strip" (effective width of trap line) about two miles wide and 2,000 miles long. This is roughly 20 per cent of the area exploited. One can now turn back to the descriptions of the results of trapping on specific trap lines and view the effects of trapping pressure by means of a sex-age analysis of the kill.

Referring again to E. O. Callison's trap line we see evidence of close utilization. This cannot be described as over-utilization as long as it continues to produce one marten per two miles of line. Nevertheless, the presence of an even sex ratio and the preponderance of young animals in the catch as well as the absence of marten tracks along the line at the close of the season make it appear that these operations are just about exhaustive. It must be remembered that this effect refers only to the area in the immediate vicinity of the trap line.

In contrast to this, data from the collective lines of the Snake River band of Indians show a quite different result. The sex ratio of the kill runs two to one in favor of males. Most of the animals exhibit the characters of old age (older than young of the year) such as long sagittal crests and greater weight. Other data have also been shown which tend to demonstrate that early season catches produce a preponderance of males and younger age classes while late season catches tend to show more females and older age classes.

It appears that trap lines which are trapping about 20 per cent of the area could produce annually about a third of the pre-season population without endangering the breeding stock. Translated into practical terms this would mean a catch of one marten from each two miles of trap line. This should produce about a thousand pelts per year from this region. The over-all catch of about 750 pelts which reaches the market is estimated as 25 per cent too low. However, this does not include marten extracted from the population which do not reach the market.

The degree of exploitation exerted by the Snake River Indians has been described in terms of sex-age-weight characteristics of the catch. After comparing this to the other

data it appears that the ultimate result of light trapping pressure permits animals to establish in areas, become senile and to usurp range which could be attractive to young immigrant animals.

Frequently the complaint is heard from Indians that there are not many marten on their lines. There is a possibility that the population is actually lower because of its over-mature character. Like timber which is allowed to become "over-mature" the growth rate and interest rate decline. Thus the Indians might prosper if they continuously harvested a "normal yield."

Removal of less than 40 per cent of the pre-season population is likely to permit the population to stagnate. Only short term data were obtained in this study but information dating back ten years suggests that marten in this region have not been subject to "cycles." It is possible that a well adjusted level of utilization in the region as a whole has prevented extreme population fluctuations.

Although it has been shown that repeated trapping can exhaust local populations the present system of registered trap lines adequately protects the breeding stock. A factor which prevents greater fur production is the time required for new animals to fill habitats evacuated by the removal of others. Re-population of trap lines is not likely to occur during the calendar limits of a trapping season because animals are reluctant to leave established home ranges during the winter. Greater utilization of the fur resource with the existing pattern of trapping can only be accomplished by an exhaustive level of exploitation which leaves the trap line vacant at the end of the season. In this way it is attractive to the new generation born on adjacent areas which spend the summer dispersing to suitable habitat. Generally, this class of the marten population is numerically superior to any other age class and can sustain the brunt of trapping pressure.

The trapping season should be restricted to the season of fur primeness. It is now four months long beginning in November. Furs trapped in February tend to be "burnt", "singed", or "springy." Trapping pressure in the time-sense is limited by the season of primeness and therefore greater utilization of this resource should not be achieved by a lengthened trapping season. Yet not to make an adequate harvest in the biological sense is to allow the population to stagnate and possibly to induce cycles.

The records described illustrate the effects of timing upon the biological characteristics of the population. Early season or late season trapping produces different biological effects. The continuation of trapping year after year on the same section of line also produces a different effect than alternation of utilization does. The re-distribution of registered trap lines can be adjusted to harvest normal biologic yields which probably could be sustained as long as the habitat is not altered. Unfortunately, economic conditions do not warrant uniform trapping pressure and human nature is difficult to regulate.

Trap spacing, time, baiting and attendance are variable factors which can be manipulated to govern the level of production of fur. The factors function differently for different species and are dominated by the inherent biological attributes of the animals. The principal animal characteristic which governs the results of a given level of trapping intensity is the numerical abundance of the species. Modifications of the travel habits because of differences in sex and age results in differential vulnerability. The sex and age characteristics of the future population depend on how much the population is exploited.

In wilderness regions where the level of land use does not require alteration of environment, habitat improvement is not necessary. The foregoing discussion has shown that the primary management procedures are trap spacing and time-control. These factors can be adjusted to tap either sex class or the broad age classes. This results in a residual population the character of which governs future production. Variations in the composition of the population can be initiated by exploitation but several years of application might be required to bring about certain desired results. Fur resource management in a wilderness region can be executed by the regulation of trapping pressure. Economic factors generally dominate biologic factors and prevent the orderly application of principles such as employed in livestock herd management.

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AGE DETERMINATION AND DATING NESTING EVENTS IN THE WILLOW PTARMIGAN [1]

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A thorough knowledge of sex and age ratios and the nesting phenology of game birds has become an integral part of modern game bird studies.

The consistent and regular moult of the primaries in game birds has proved valuable in facilitating the assembling of comprehensive data on nesting events when the moult pattern is understood.

This regular wing moult pattern was first described and used as an accurate aging method by Bureau (1911) for the common partridge, *Perdix perdix*, and the red-legged partridge, *Alectoris rufa* (1913). In later studies, the wing moult and its use in age determination and dating of nesting events have been described for the bobwhite quail, *Colinus virginianus* (Petrides and Nestler, 1943; Thompson and Kabat, 1950; Petrides, 1952; and Reeves, 1952); the pheasant, *Phasianus colchicus* (Buss, 1946; Kabat, Thompson and Kozlick, 1950); the ruffed grouse, *Bonasa umbellus* (Bump *et al.*, 1947; Hale and Wendt, 1951). McCabe and Hawkins (1946) added further data on the wing moult of the partridge; Thompson and Taber (1948) were the first to use wing moult data for producing reference tables for dating nesting events in pheasants, partridges and bobwhite quail.

A similar reference chart for dating nesting events in the willow ptarmigan, *Lagopus lagopus*, is presented here as an aid in assembling nesting data. Whereas much material on the nesting of the willow ptarmigan is available in the Norwegian literature, very little is known and recorded about the breeding of this bird in Canada and Alaska.

The willow ptarmigan is the national game bird of Norway and has been the subject of a long sequence of important papers by Norwegian biologists and ornithologists.

My own experience with aging of willow ptarmigan is slight; the data presented in this paper was collected by Hagen, Holt, Høst, Johnsen, Kristoffersen and Olstad of Norway, and as their various papers are written in Norwegian (a few in German) they are not generally known abroad, nor are they accessible to North American wildlife biologists. It was therefore considered that a translation and correlation of the available data for construction of a table for dating of nesting events in the willow ptarmigan would be desirable. Such a table has not been published although the necessary data are available and only need to be extracted from a number of papers and correlated.

Acknowledgment is made to Dr. C. H. D. Clarke, of the Ontario Division of Fish and Wildlife, and to Mr. Stuart S. Peters, of the Newfoundland Wildlife Division for reading the manuscript and for helpful sugges-

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tions and valuable information about willow ptarmigan in Canada.

ADULTS

Before a discussion of age determination in juvenile willow ptarmigan, it may be opportune to describe how juvenile birds may be told from adult birds. Two methods are used for dead specimens.

Dahl (1922) mentions the "lower jaw method," also employed in determining age in a number of other game birds. The willow ptarmigan is lifted by the lower mandible which will yield and bend in a young bird, but not in an adult ptarmigan. Holt (1951) refers to the "cranium method," whereby the bird's head is held between the index and middle fingers and the thumb presses on the forehead. In young birds the cranium will break, whereas it is not possible to press in the brain case in an adult ptarmigan when held in the described manner.

According to Johnsen (1928) the base of the lower mandible is light yellowish in juvenile willow ptarmigan until late autumn and early winter; the adult birds have black bills; in some individuals the light-coloured base of the lower mandible is retained so that some adult birds in that respect may resemble juveniles. The bill in juvenile birds, however, is smooth, whereas furrows are found at the chin edge in adult birds, being marks where the horn sheath has been shed during the July-August moult.

Hagen (1937) showed that the willow ptarmigan, like most gallinaceous birds, retained the outer two primaries during the first year and moulted the first eight primaries during the first few months of their lives. Hagen (1942) also showed that adult birds were heavier during the shooting season than juvenile birds of the year. These weight differences, however, were too small and too variable to be of use in sex and age determination. Average weights for September were: adult males 584 grams, juvenile males 567 grams; adult females 517 grams, juvenile females 506 grams. A willow ptarmigan is almost fully developed and has attained the weight of adult birds when 2½ months old or a little older, as shown by Holt (1951).

JUVENILES

Whereas such superficial examination of a willow ptarmigan may have proved that the bird is a bird of the year the presence of a bursa Fabricii would, of course, be a final criterium. If the bird's primary moult is not yet completed it is possible to determine its age in weeks and also to trace back and reconstruct phenology of the nest from which the bird came.

Before discussing such a method it should be pointed out that two Norwegians have made very thorough studies of the development of the young willow ptarmigan, namely Hagen (1937), showing the complete moult pattern and correlating weight increase with average development and tail moult, and presenting diagrams showing tail and wing development in relation to age; and Holt (1951), who correlates wing lengths and body weights of juvenile birds, presenting a wing-length-weight-age curve.

As the first primary in the willow ptarmigan is shed when the bird is 18 days old, other means must be employed to age small chicks. For that purpose wing lengths and weights have been extracted from Holt's data and are presented in Table 1.

TABLE 1.—AGE DETERMINATION OF WILLOW PTARMIGAN CHICKS, AGED 1–20 DAYS (DATA FROM HOLT, 1951)

Age in days	Wing length in mm	Weight in grams
1	20–24	14–15
2	20–26	15–16
4	31–43	20–25
6	44–52	28–30
8	52–62	30–37
10	65–80	41–49
12	70–79 (80)	47–59
14	64–90	65–73
16	65–88 (90)	89
18	96–105	77–100
20	95–110	108–117

As shown by Hagen (1937) the young willow ptarmigan drops its first primary when approximately 18 days old (earlier, by the way, than any of the other game birds studied so far), and young birds between this age and three months (when the moult is complete) can be aged by use of the reference chart (Table 2).

The five constituents of such a chart are: earliest and latest date of egg-laying; average number of eggs per clutch; egg-laying rate; length of incubation period; and rate of primary wing moult.

TABLE 2.—REFERENCE CHART FOR DATING WILLOW PTARMIGAN NESTING EVENTS

Date of 1st egg	Age[1] Primary dropped	1st day of incubation	Date of hatching	2½ wks. 1	3½ wks. 2	4 wks. 3	5 wks. 4	6 wks. 5	6½ wks. 6	7½ wks. 7	9 wks. 8	10 wks. ¼ grown	11 wks. ¼ grown	12 wks. ¼ grown	13 wks. compl.	Age in days at Hunting Season opening on 1 Sept.	10 Sept.	20 Sept.	1 Oct.	15 Oct.	1 Nov.
May 1	May 11	June 1	June 19	June 26	July 1	July 6	July 11	July 17	July 24	Aug. 5	Aug. 12	Aug. 19	Aug. 26	Sept. 2	92	101	111	122	136	153
8	18	8	26	July 3	8	13	18	24	31	12	19	26	Sept. 2	9	85	94	104	115	129	146
15	25	15	July 3	10	15	20	25	31	Aug. 7	19	26	Sept. 2	9	16	78	87	97	108	122	139
22	June 1	22	10	17	22	27	Aug. 1	Aug. 7	14	26	Sept. 2	9	16	23	71	80	90	101	115	132
29	8	29	17	24	29	Aug. 3	8	14	21	Sept. 2	9	16	23	30	64	73	83	94	108	125
June 5	15	July 6	24	31	Aug. 5	10	15	21	28	9	16	23	30	Oct. 7	57	66	76	87	101	118
12	22	13	31	Aug. 7	12	17	22	28	Sept. 4	16	23	30	Oct. 7	14	50	59	69	80	94	111
19	29	20	Aug. 7	14	19	24	29	Sept. 4	11	23	30	Oct. 7	14	21	43	52	62	73	87	104
26	July 6	27	14	21	26	31	Sept. 5	11	18	30	Oct. 7	14	21	28	36	45	55	66	80	97
July 3	13	Aug. 3	21	28	Sept. 2	Sept. 7	12	18	25	Oct. 7	14	21	28	Nov. 4	29	38	48	59	73	90
10	20	10	28	Sept. 4	9	14	19	25	Oct. 2	14	21	28	Nov. 4	11	22	31	41	52	66	83
17	27	17	Sept. 4	11	16	21	26	Oct. 2	9	21	28	Nov. 4	11	18	15	24	34	45	59	76
24	Aug. 3	24	11	18	23	28	Oct. 3	9	16	28	Nov. 4	11	18	25	8	17	27	38	52	69
31	10	31	18	25	30	Oct. 5	10	16	23	Nov. 4	11	18	25	Dec. 2	1	10	20	31	45	62
Aug. 7	17	Sept. 7	25	Oct. 2	Oct. 7	12	17	23	30	11	18	25	Dec. 2	9	..	3	13	24	38	55
14	24	14	Oct. 2	9	14	19	24	30	Nov. 6	18	25	Dec. 2	9	16	..	..	6	17	31	48
21	31	21	9	16	21	26	31	Nov. 6	13	25	Dec. 2	9	16	23	..	..	..	10	24	41
28	Sept. 7	28	16	23	28	Nov. 2	Nov. 7	13	20	Dec. 2	9	16	23	30	..	..	..	3	17	34

MATURE

IMMATURE

[1] The actual ages when the first to the eighth primaries are dropped are in days:
18 (1st), 25 (2nd), 30 (3rd), 35 (4th), 40 (5th), 46 (6th), 53 (7th), and 65 (8th).

Egg-laying in 129 Norwegian willow ptarmigan nests in Gudbrandsdalen began between 19 May and 13 July (Olstad, 1931). On the island of Karlsøy, egg-laying in 28 nests began between 18 May and 16 June (Kristoffersen, 1933). Holt (1951) gives 15 May as the first date for egg-laying in two nests out of a total of 21 nests. Høst (1938) had a captive willow ptarmigan laying her first egg on 6 May. In order to make allowance for early and late nests the reference chart includes nests with egg-laying beginning between 1 May and 31 July.

The available information on egg-laying shows that the dates in Canada and Alaska fall within the Norwegian time limits. Dr. C. H. D. Clarke (*in litt.*) remarked: "The data fit Canadian and Alaskan conditions surprisingly well."

Bent (1932) summarizes North American nesting data for the willow ptarmigan:

Lagopus lagopus albus. Northern Alaska: 68 records, 25 May to 10 July; 34 records, 6 to 25 June; Arctic Canada: 37 records, 2 June to 7 July; 19 records, 10 to 21 June; Labrador Peninsula: 18 records, 1 to 30 June; 9 records, 6 to 23 June.

Lagopus lagopus alleni. Newfoundland: 11 records, 12 May to 30 June; 6 records, 8 to 12 June.

Lagopus lagopus alexandrae. Southern Alaska and British Columbia: 3 records, 28 May, 25 and 26 June.

Summarizing the data on these 205 North American willow ptarmigan nests, the earliest and latest records of nests containing eggs are 12 May and 10 July. So there should be ample allowance for very early and extremely late nests in the reference chart. Dr. Clarke informs me that: "breeding on the Hudson Bay coast may even be retarded, as Mr. C. E. Hope, of the Royal Ontario Museum has a record of a bird collected on July 7, at a nest with 8 eggs, that still had one egg in the oviduct." This particular nest could have been found containing eggs as late as 28 July, as the incubation period is 21 days.

The average number of eggs in 129 Norwegian willow ptarmigan nests was 9.5, varying from 4 to 13 (Olstad, 1931). Bent (1932) gives 7 to 10 eggs as average for willow ptarmigan in North America, as many as 17 have been found in one nest, and in late or second nests as few as 5 or 6.

Only a few scattered records were found on the egg-laying rate of this species. Høst (1938) had willow ptarmigan in captivity; one hen laid 14 eggs at intervals of 26 hours, or in 15 days. Kristoffersen (1937) has information about the egg-laying in four wild nests and in all cases eggs were laid on consecutive days, but only the laying of respectively two, five, three and two eggs was recorded. Olstad (1932) records a willow ptarmigan laying 11 eggs in 12 days. The egg-laying rate in the species has been determined at 1.1 day per egg.

The average egg-laying period for the willow ptarmigan is $10 \times 1.1 = 11$ days.

It was shown by Høst (1938) and Olstad (1932) that the willow ptarmigan begins to incubate on the day when the last egg is laid.

Information on the length of incubation is available from wild nests as well as from artificial incubation. Kristoffersen (1937) recorded the exact incubation period in three nests and found it to be respectively 20 days and 10 hours, 20 days and 12 hours, and 20 days and 21 hours. Høst (1938) had a willow ptarmigan hatch her clutch in captivity in 22 days. Høst also records the incubation periods for 158 willow ptarmigan eggs in six settings in an artificial incubator and found $21\frac{1}{2}$, 21, 21, 21, $21\frac{1}{2}$ and $21\frac{1}{2}$ days. Holt (1946) found that 13 captive willow ptarmigan were sitting for between $20\frac{1}{2}$ and 22 days, average $21\frac{1}{4}$ days. Four captive birds in nest boxes hatched their eggs in $21\frac{1}{4}$ days (variation 21–$21\frac{1}{4}$ days). A total of 121 eggs were hatched by domestic fowls which sat for $21\frac{1}{4}$ days (variation $20\frac{1}{2}$–22 days). In an electric incubator the incubation period was a little longer, namely $21\frac{3}{4}$ days (variation 21–$23\frac{1}{2}$ days) for 500 eggs.

The mean incubation period for the willow ptarmigan is 21 days.

The data on the primary wing moult of the willow ptarmigan is taken from Hagen (1937) who worked with marked wild birds which were caught and recaptured.

DATING NESTING EVENTS

We have therefore a method of estimating the age of willow ptarmigan.

By use of Table 2 it is possible to age juveniles to the nearest week (or by interpolation: days) and arrive at the approximate dates for laying of the first egg, first day of incubation and date of hatching.

By primary dropped is meant the primary shed most recently, *i.e.* a missing one or a very short one (*cf.* Fig. 1).

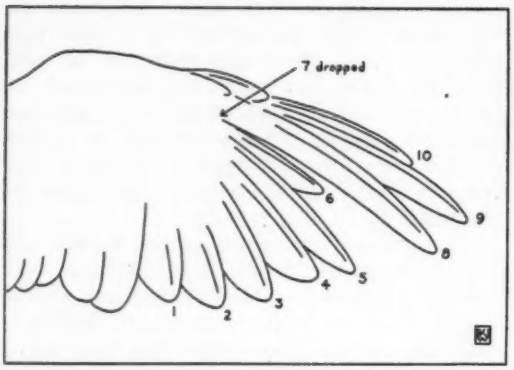

FIG. 1. Right wing of willow ptarmigan, showing moulting primaries 1–8, of which No. 7 is the latest one shed indicating an age of approximately 7½ weeks, *cf.* Table 2. Location of most recently shed primary is best determined by removal of ventral primary coverts.

Whereas maturity data collected this way can be of value in setting shooting dates for pheasant, partridge, ruffed grouse and bobwhite quail, a similar use of ptarmigan information is not particularly important in North America as ptarmigan except in Newfoundland live mostly beyond the fringes of settlement; they are mainly shot by natives, except in Quebec and Manitoba, and strict open seasons would be impossible to control anyway.

Collection of sufficient data will provide valuable information about the onset of the egg-laying season, the peak of oviposition, possible renesting, the main period of hatching, and other facts of paramount importance for an evaluation of nesting success and factors affecting it. With such a technique it is possible to assemble much nesting data which—especially for a bird like the willow ptarmigan, living in desolate places—would otherwise be extremely laborious to collect.

SUMMARY

The regular wing moult in the willow ptarmigan has been utilized in devising a reference chart from which can be obtained the approximate ages of the birds examined as well as the dates for onset of the egg-laying, incubation and hatching.

Methods for distinguishing adult from juvenile ptarmigan, and data for determining the age in ptarmigan chicks are also presented.

The material utilized was collected by Norwegian biologists. The basic facts employed—in addition to the primary moult data—were: commencement of the egg-laying period varying between 18 May and 13 July; average number of eggs per nest 10; egg-laying rate 1.1 egg per day; duration of the incubation period 21 days.

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DUCK PRODUCTION AT GRAY'S LAKE, IDAHO, 1949–1951[1]

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Gray's Lake, a high altitude, 22,000-acre marsh in southeastern Idaho, has undergone little apparent change since the valley was settled 65 years ago. The open water areas present then still persist. Tules still dominate and choke most of the marsh. In the spring the marsh is a vibrating "bird factory" full of life and movement. At least eleven species of ducks nest at Gray's Lake in addition to the coot, the Canada goose and a highly interesting variety of non-game birds.

The present study attempts to evaluate the waterfowl production on Gray's Lake by determining: (1) the species and approximate numbers of waterfowl utilizing the area; (2) the distribution and density of nesting waterfowl on the marsh-adjacent meadows; (3) the extent of nest and brood mortality.

Interest of the U. S. Fish and Wildlife Service and the Idaho Fish and Game Department in Gray's Lake as a waterfowl management area encouraged the Wildlife Research Unit to undertake the study. Field work covered three nesting and brooding seasons: May 16 to October 1, 1949; April 1 to September 15, 1950; and April 5 to September 14, 1951.

DESCRIPTION OF THE AREA

Gray's Lake is a marsh located in Bonneville and Caribou Counties. It is approximately 9 miles long and 4 miles wide. To the south, 120 airline miles, is the famous Bear River marsh in Utah. Situated at 6,386 feet elevation, the lake is completely frozen

[1] Contribution from the Idaho Cooperative Wildlife Research Unit. The University of Idaho Forest, Wildlife and Range Experiment Station, the Idaho Fish and Game Department, the U. S. Fish and Wildlife Service and the Wildlife Management Institute cooperating.

over from November to March or mid-April. The Caribou Range lies to the east. The marsh is bordered by rolling hills covered with sagebrush and aspen except along the southeast side where farm lands occur.

Gray's Lake watershed is restricted to a relatively small area by the closeness of the mountains (Figure 1). Only four small

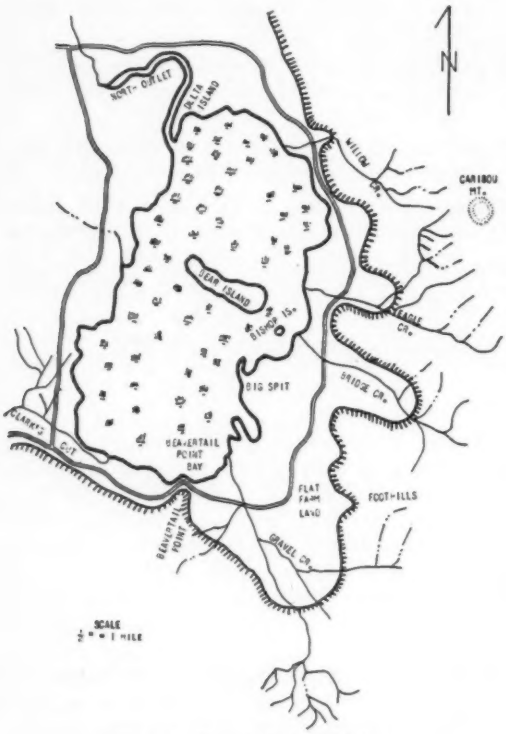

FIG. 1. Gray's Lake, Idaho.

streams empty into the marsh basin. Very little water enters the marsh after the spring freshets have subsided. Complete water inflow records for the year 1942 show that a total of 156 second-feet was reaching the lake on June 1, and only 8 second-feet six weeks later (Oster, 1942). The average water depth is about 3½ feet. Because of irrigation withdrawals, combined with evaporation and transpiration losses, water decline is severe throughout the summer. In some years the marsh bed becomes almost completely dry by September. Water is discharged from the lake by two outlets, one natural and the other artificial.

Plant cover for nesting, brooding, and escape, in the proper juxtaposition with open water, represents ideal conditions for waterfowl. Solid, dense stands of otherwise good cover are usually avoided. This condition typifies the vast majority of Gray's Lake. During the spring an estimated 90 per cent of the marsh is covered with emergent vegetation, and 10 per cent is open water. By mid-summer due to reduction in water level and new growth of emergent plants the ratio is even less favorable. Open water is then confined to the sloughs in the southeastern corner of the lake, to discontinuous stretches along the shore line, and to numerous small muskrat openings and channels scattered throughout the main body of the marsh.

Beginning at the sagebrush-grass community along the edge of the marsh, baltic rush (*Juncus balticus*)[1] is the first dominant semi-aquatic encountered. It occupies the zone that is inundated most of the year, but which is usually dry during mid-summer. Sedges (*Carex rostrata* and *C. aquatilis*) and bur-reed (*Sparganium eurycarpum*) occupy the shallower waters with the latter better adapted to deeper areas near the shore. Next in sequence is cattail (*Typha latifolia*) which is scattered sparsely throughout extensive stands of bulrush, but which also occurs as the dominant cover at the mouth of in-flowing creeks. On the basis of aerial photographs of a portion of the marsh taken in late June, 1950, it is estimated that, areawise, cattail exists in a ratio of about 1 to 4 with hardstem bulrush (*Scirpus acutus*), the dominant emergent of the entire marsh.

Submerged aquatics grow luxuriantly in most of the open water of the marsh. The dominant submerged aquatic is water milfoil (*Myriophyllum exalbescens*), with bladderwort (*Utricularia vulgaris*) abundant along the shore and in stagnant pools. Seven species of pondweeds were identified, with clasping leaf (*Potamogeton richardsonii*) the most abundant. Along the natural outlet channel of the lake, yellow pondlily (*Nuphar polysepalum*) occurs in abundance and its fronds are much used by waterfowl for brood cover. Smartweed (*Polygonum natans*) was the only member of this genus found in the marsh. Muskgrass (*Chara* sp.) and green algae are relatively abundant in all open

[1] Plant names according to Davis, The Flora of Idaho, 1952.

water areas. There are virtually no submerged or floating aquatic food plants.

LAND USE

The economy of Gray's valley is largely confined to dairying and beef cattle. Small grains are grown on the higher lands from one to two miles from the marsh. A few farmers plant small tracts of grain at the very edge of the lake where they are highly vulnerable to waterfowl and sandhill crane depredation.

The bulk of the farm lands are adjacent to the southeastern side of the lake. Although several small acreages of hay, chiefly alfalfa, are harvested each year, the principal crop is wild hay, a complex mixture of grasses, rushes, sedges and forbs.

The remainder of the land surrounding the lake is used mainly for grazing livestock during the snow-free period of the year. Cattle roam the entire west and northern sides and often work their way as much as a quarter-mile into the dense tules. Sheep are grazed during the summer on the grass-forb pastures along the northeast side.

Scarcely more than sixty families earn their livelihoods from the dairying and livestock industry of Gray's Lake basin.

NEST STUDY METHODS

Land nests were located by systematically walking through an area or by using a dog. Dragging a rope or telephone wire between two men was successful only in grassy areas. The most productive method of locating land nests was by the use of a dog. Over-water nests of diving-ducks were located by flushing the hens, which were inclined to leave their nests on the approach of a boat. Diver hens habitually flush some distance from their nests, hence searching for the nests was time consuming. The best method for locating nests on the floating cattail islands was by the use of a dog. These islands often would not support the weight of a man.

When a nest was found its location was marked by flags and/or by mapping.

A time-sampling method was used to measure nest production. The method assumes that all but a small percentage of ducks nesting in emergent marsh vegetation will locate their nests within 20 yards of open water. An outboard motorboat was operated at a set speed for a predetermined period, cruising immediately adjacent to the edge of vegetation. Markers were set at the start and finish of each sample. Forty 10-minute samples were randomly established in 1949, but these were changed to twenty 20-minute samples at a faster speed in 1950 and 1951, thus permitting a greater coverage of nesting habitat. All samples, both land and marsh, were re-run at approximately 10-day intervals to locate new nests and to revisit those already found.

BREEDING POPULATION OF DUCKS

The mallard frequents spring-fed sloughs in the willowy delta of Eagle Creek as early as February. By mid-May most of the other breeding species have arrived. Gray's Lake is not within one of the main northward migration routes and it is not extensively utilized as a resting or stop-over area during the spring. The breeding population was estimated at 15,000 ducks in 1949, 12,000 in 1950, and 10,000 in 1951. Table 1 shows the estimated percentage composition of the duck population.

TABLE 1.—ESTIMATED PERCENTAGE COMPOSITION OF THE BREEDING DUCK POPULATION AT GRAY'S LAKE, IDAHO

Breeding Species	1949	1950	1951
Mallard	31	24	32
Pintail	19	23	23
Canvasback	11	9	9
Redhead	10	11	9
Teal; Cinnamon, Bluewinged, Greenwinged	12	11	10
Scaup, Lesser	8	9	5
Ruddy duck	5	7	6
Gadwall	2	3	5
Shoveler	2	3	1

Approximately 50 per cent of the three-year total breeding population was mallards and pintails. They, like all the ducks except the gadwall, declined in breeding numbers over the three-year study. A reduction in the mallard population was responsible for about one-half the total population decline from 1949 to 1950. The most obvious decline observed in 1951 was in redheads.

During this three-year study 530 duck nests were found: 1949—131, 1950—233, and 1951—166. Of this total, nest histories of 489 were successfully terminated: 128,

TABLE 2.—DISTRIBUTION OF DUCK NESTS BY NEST SITES, 1949–1951

SPECIES	LAND				MARSH				
	Island	Lake shore	Field	Haystack	Cattail island	Bulrush	Cattail-bulrush mixture	Muskrat house	Total nests
Mallard	28	21	15	7	35	17	3	12	138
Pintail	36	33	28	1	..	..	..	..	98
Redhead	..	..	..	..	7	79	1	..	87
Teal, BW/Cinn	16	29	21	1	14	1	..	1	83
Canvasback	..	..	..	..	4	45	2	1	52
Gadwall	10	9	3	..	2	..	..	..	24
Scaup, Lesser	2	5	2	..	6	6	1	..	22
Ruddy	..	..	..	..	9	8	2	1	20
Shoveler	1	1	3	..	..	..	..	..	5
Teal, GW	1	3	..	..	..	..	..	..	4
American Widgeon	1	..	..	..	..	..	..	..	1
Totals	95	101	72	9	77	156	9	15	534
Per cent	(18)	(19)	(13)	(2)	(14)	(29)	(2)	(3)	(100)

213 and 148, respectively, for the three seasons.

NESTING COVER AND SITE

Hardstem bulrush is the dominant emergent type in the marsh and most extensively used by the four species of diving ducks. Of 181 divers' nests found, 76 per cent were in the bulrush type and 14 per cent in cattails. Table 2 shows the distribution of duck nests by sites. Cover is almost uniformly poor early in the nesting season.

The bulrush type accounted for the majority of nests in the marsh. Cattail islands form an excellent nesting habitat. During high water they float, and in late summer they rest on the bottom. Thirty per cent of all marsh nests were found on these mats or islands.

Certain land areas around the marsh were especially productive and in total contained about 18 per cent of the nests in 1951. Goose and crane nests were also common on the temporary islands on Big Spit. Bishop Island of about 5 acres had 21 duck nests in native grass cover. Nesting sites adjacent to the marsh, but not on temporary islands, were classified as lake shore sites. In 1951 one-fifth of the nests were in these areas.

Ninety-seven per cent of all marsh nests were located within 15 yards of the nearest open water. The importance of interspersion of cover and open water was evident with respect to marsh nests and conforms to the results of Williams and Marshall (1938). Five miles of belt transect totalling 44 acres, run through the central portion of the marsh in the unbroken stands of bulrush revealed not a single duck nest.

NEST SUCCESS

Nest success was uniformly high all through the study: 68 per cent in 1949, 70 in 1950, and 72 in 1951. These data indicate that no pronounced nesting hazards existed at Gray's Lake in the three-year study. Approximately 70 per cent of all nests were successful. This figure is cited by Kalmbach (1939) as a satisfactory management goal for any given area.

Table 3 summarizes the nesting success

TABLE 3.—NESTING SUCCESS 1949–1951 OF EIGHT SPECIES OF DUCKS COMPRISING 98 PER CENT OF ALL NESTS UNDER OBSERVATION AT GRAY'S LAKE

Species	No. of nests terminated	No. of nests successful	Per cent successful
Redhead	85	72	85
Gadwall	20	16	80
Pintail	96	68	71
Mallard	124	85	69
Canvasback	51	34	67
Scaup, Lesser	20	13	65
Teal, BW and Cinn.	66	38	58
Ruddy	18	10	56

by species. Of the four most abundant nesters, accounting for 76 per cent of all the nests, the redhead had an 85 per cent nesting success; pintail, 71; mallard, 69; and teal, 58.

NEST LOSS

The 147 unsuccessful nests were classified as follows: destroyed by mammals (skunk, mink, badger) 29 per cent; by birds, 22; by grazing, 3; by unknown predator, 7; by other unknown cause, 11; and deserted, 28 per cent. The crow was the principal avian predator on nests. The degree of nest concealment was recorded to determine the relationship between concealment and nest predation. There appeared to be little correlation between the two in the 83 predator-destroyed nests. Only those which had a full clutch and were then deserted by the female were classed as deserted nests. Desertion was especially prevalent among mallards and ruddys.

Trampling by cattle was an insignificant cause of nest failure. Although a herd of 500 cattle grazed on a sagebrush spit of land on which 62 nests were found, only one was destroyed by trampling. Agricultural practices such as fall plowing or haying had little influence on nesting ducks since most of the crop fields are a half to two miles from the marsh and not habitually used by ducks. Spring burning of stubble is not a common practice in the area. No nest loss due to flooding was encountered during the course of the study.

EGG PRODUCTION

Of the 4,140 terminated eggs in all nests, 2,567 (62 per cent) hatched (Table 4). Egg loss from all sources in successful nests amounted to 12 per cent, of which embryonic mortality and infertile eggs were the two major causes. Young that died during hatching, or hatched and died after the hen had left the nest, were few in number.

Generally there was a progressive decline in brood size (Table 5). Only two species, canvasback and redhead, had sufficient Class III brood counts to be significant, however.

DUCKLING PRODUCTION

Production on the marsh was much lower in 1951 than in 1950 or 1949 based not only upon a smaller estimated breeding population but upon nesting results. The number of nests per 100 habitat acres was 47, 39, and 15, respectively, in 1949, 1950, and 1951. Habitat acres for marsh nesting ducks were considered to be the edges or strips of vegetation beginning at open water and extending inward 15 yards. Each sample covered 1.2 miles of vegetative edges containing 6.55 habitat acres (1.2 miles by 15 yds.); thus, 20 samples included 24 miles of edge and 131 habitat acres. For all species of ducks there were 2.55 nests per sample in 1950 and 0.95 in 1951. There were 2.10 nests per mile of edge in 1950 and 0.79 in 1951, or 39 nests per 100 habitat acres in 1950 and 15 in 1951.

The two plant species available as nesting

TABLE 4.—SUMMARY OF EGG DATA BY SPECIES FOR ALL DUCK NESTS TERMINATED, 1949–1951, INCLUSIVE

Species	Fate of eggs in successful nests							Percentage of egg success	
	Total eggs	Live hatch	Infertile	Dead embryo	Late or dead hatch	Missing from nest	Predation	Total terminated nests	Successful nests
Mallard	689	619	21	28	8	13	..	61	90
Pintail	528	469	21	14	2	18	4	64	89
Redhead	655	534	42	50	7	22	..	70	82
Teal, Bw/Cinn	373	346	13	5	..	7	2	54	93
Canvasback	283	236	10	25	1	11	..	56	83
Gadwall	145	133	..	11	..	..	1	75	92
Scaup, Lesser	120	115	3	..	1	1	..	64	96
Ruddy	77	65	4	5	3	..	..	49	84
Shoveler	27	23	3	1	..	..	..	66	85
American Widgeon	10	7	..	3	..	..	..	70	70
Totals	2,928	2,567	118	142	22	72	7	62	88

TABLE 5.—AVERAGE HATCH FOR DUCKS AND SUMMARY OF BROOD CENSUS DATA 1949–1951 INCLUSIVE. FIGURES IN PARENTHESES ARE NUMBERS OF BROODS COUNTED TO COMPUTE AVERAGE SIZE

Species	Average hatch	Average Brood by Age Group			Total Broods
		Class I [1]	Class II [2]	Class III [3]	
Mallard	7.4	6.8 (29)	5.3 (17)	5.0 (8)	54
Pintail	6.9	6.3 (12)	7.1 (9)	6.4 (14)	35
Redhead	7.6	6.3 (186)	6.2 (105)	6.2 (48)	339
Teal, Bw/Cinn	9.0	6.3 (31)	6.5 (19)	6.4 (11)	61
Canvasback	6.9	6.5 (201)	6.0 (225)	5.7 (127)	553
Gadwall	8.8	8.3 (65)	5.7 (23)	.. ..	88
Scaup, Lesser	8.5	7.2 (202)	6.1 (119)	.. ..	321
Ruddy	6.5	6.0 (300)	5.3 (89)	5.0 (2)	391
Shoveler	7.7*	.. ..	8.0 (1)	7.0 (1)	2
American Widgeon	7.0**	4.5 (6)	.. ..	.. ..	6
All Ducks	7.4	6.5 (1033)	6.1 (607)	5.7 (211)	1,851

* 1 year. ** 2 years.
[1] Class I—Young less than one-third grown.
[2] Class II—Young one-third to two-thirds grown.
[3] Class III—Young more than two-thirds grown.

cover on the marsh sample were broad-leaved cattail and hardstem bulrush. The latter provides good nesting cover for diving ducks whereas the former is very poor. The marsh is not uniformly productive and the eleven marsh samples in the southeastern section averaged more nests than the nine samples located in isolated open water areas around the periphery of the marsh. The samples were randomly established to census the open water areas of the marsh, but apparently there was not a random distribution of marsh nests. Although each sample was established along a definite vegetational edge there was a marked variation in the nest-density potential of the samples.

In 1950 and 1951, five land cover types were sampled for duck nest density. On seven land samples, a total of 525 acres contained 68 nests in 1950 and 114 in 1951. The density of nests per 100 acres was 13 in 1950 and 22 in 1951. An intensive search during the post-nesting season revealed that approximately 25 per cent of the nests in the marsh sampling units were not found. The methods in use precluded determining the influence of renesting.

There appeared to be a progressive decline in the productiveness of the marsh during the three-year study period (Table 6). There was, however, nearly a 50 per cent increase in production on the land areas.

WATERFOWL MORTALITY FROM MUSKRAT TRAPPING

During the muskrat trapping period (April 10–20) the waterfowl population was estimated to be 5,000 and 4,000 ducks; 1,500 and 1,200 coots; 1,000 and 800 Canada geese in 1950 and 1951 respectively.

Of the duck population present during the trapping season, about one per cent was caught in 1950 and about two per cent in 1951. Coots accounted for a considerable

TABLE 6.—CALCULATED DUCK PRODUCTION PER 100 HABITAT ACRES

Sample Type	Nests per 100 habitat acres		25 per cent correction		Per cent successful nests		Ave. hatch per successful nest		No. of juveniles produced
Land									
1950	13	×	1.33	×	70	×	7.3	=	88
1951	22	×	1.33	×	72	×	7.7	=	162
Marsh									
1949	47	×	1.33	×	68	×	7.6	=	323
1950	39	×	1.33	×	70	×	7.3	=	464
1951	15	×	1.33	×	72	×	7.7	=	111

reduction in trapping success. In 1950, 14 per cent of the estimated coot population was caught and 18 per cent was taken in 1951. Four-fifths of all coots trapped were reported dead in the traps; an unknown but high percentage was killed by trappers. Fifteen geese were reported trapped, ten of which were released uninjured. On several occasions, shortly after the trapping season, flying geese were observed with traps attached to their legs. All 41 trappers were censused in 1950, but only those trappers operating in the same area as in 1950 were checked in 1951.

SUMMARY

1. Gray's Lake in southeastern Idaho is a 22,000-acre marsh at an elevation of 6,386 feet, averages 3 feet in depth, and is 90 per cent covered with emergent vegetation. Open waters are peripheral and found mostly in the southeastern quarter. The dominant emergent plant over the entire marsh is hardstem bulrush; the dominant submerged aquatic is water milfoil. Muskgrass and green algae are relatively common in all open water areas.

2. The principal duck species were (1949–1951): mallard, pintail, redhead, blue and green-winged teal, canvasback, gadwall, lesser scaup, and ruddy.

3. Nesting success of all duck species averaged 70 per cent during the three-year study.

4. There was an 88 per cent egg success in successful nests. The major cause of egg failure in successful nests was the death of the young during incubation.

5. Production of ducks in the marsh declined from 47 nests per 100 habitat acres in 1949, to 39 in 1950 and to 15 nests per 100 habitat acres in 1951. The southeastern end of the marsh, wherein lies the largest continuous body of open water, contained 64 per cent of the duck nests.

6. Waterfowl mortality resulting from spring muskrat trapping was not high. One per cent of the duck population was trapped in 1950 and two per cent in 1951. Fourteen per cent and 18 per cent of the coot population were trapped in 1950 and 1951, respectively.

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REGIONAL DIFFERENCES IN SIZE AND PRODUCTIVITY OF DEER IN WEST VIRGINIA

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West Virginia deer hunting was regulated by a buck law during the four decades prior to 1951. One of the consequences of this regulation was development of excessive deer populations in certain parts of the state. An investigation of problems associated with rapidly increasing deer populations was established by the Conservation Commission in 1947. This work was undertaken with Pittman-Robertson funds.

The project has now been active continuously for eight years in many phases of life history and management of deer. The phase reported here has the following objectives—to study deer range potentials as indicated by physical development of deer, and to compare skeletal growth, body weight, antler development and breeding potential of the deer comprising various herds in the state.

Before this study was established it was recognized that there were distinct differences in size and productivity of deer between various parts of West Virginia but the magnitudes of these differences were unknown. Information about physical characteristics and productivity may be useful in many ways. Some of the values with respect to productivity were expressed by Morton and Cheatum (1946) as follows:

> "Knowledge of the breeding potential of a game species is essential to its proper management. Regional differences in productivity may demand differences in diagnosis and treatment. In the white-tailed deer (*Odocoileus virginianus*), proper management may require adjustments in laws relating to bag limits, open seasons, and legal game (buck, antlerless, and 1-deer laws). In cases of low fecundity, efforts to adjust the environment to increase the number of young produced may be feasible. These matters should be considered in the formulation of policy intended to make the best possible use of game resources."

A direct relation has been observed between adequacy of forage and ability of female deer to produce and rear fawns. Gerstell (1938) noted low fawn production in sections of over-browsed deer range in Pennsylvania. O'Roke and Hamerstrom (1948) reported a similar relationship for the George Reserve deer herd in Michigan. Investigations conducted in New York by Morton and Cheatum (1946) and by Cheatum and Severinghaus (1950) have produced evidence that fertility and fecundity of deer are directly related to range quality.

Information on anatomical characteristics of deer may also indicate range quality. Severinghaus *et al.* (1950) presented evidence that variations in antler development are related to forage adequacy. Differences in body weight and/or antler development were attributed to differences in range conditions by Johnson (1937), Gerstell (1938), Park (1938), Park and Day (1942) and Leopold (1943). In West Virginia, reduction of a high deer population resulted in a significant weight increase among fawns killed in the same area the next year (Gill, 1953b).

Most of the foregoing authors cited inadequate quantity of forage during winter as the cause of reduced size and/or productivity of deer. Recently Dunkeson and Murphy (1953) reported a direct relationship in Missouri between soil fertility and body weight, antler development, and reproductive potential. Differences in size and productivity of West Virginia deer may also be related to differences in quality rather than quantity of forage. In this state deer population increases were controlled before any extensive ranges became overbrowsed.

Population control was secured by adoption of hunter's-choice deer seasons beginning in 1951. Deer of either sex have been

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legal game during the past four years (DeGarmo, 1951, 1952, 1952a and Gill, 1953b, 1954a). Increased deer harvests under liberalized regulation have permitted collection of data on about 17,000 deer since 1951. Analysis of the data, as reported in this paper, indicates that the state can logically be divided into four regions whose deer have distinct size and reproductive characteristics.

The distribution of regions (Fig. 1) roughly resembles that for physiological subdivisions (McKeever, 1952). The regions and subdivisions which include most of the area of each are: West, Ohio-West Virginia Hills; Allegheny, Allegheny Plateau; South, Cumberland Mountains; and East, Allegheny Ridges and Valleys.

MATERIALS AND METHODS

West Virginia hunters are required by law to present their deer for tagging at one of the official checking stations established in each county open for hunting. This checking system provides an excellent census of the legal kill. Since the deer checking law is seldom violated, deer brought to each checking station constitute a sample which is virtually unbiased as to sex and age.

Certain checking stations were selected as "aging" stations and technicians were assigned to them (Fig. 1). Selection of these aging stations was not made at random. Rather, an effort was made to secure more information from certain areas than from others.

Samples for individual aging stations were treated as random samples from the particular areas involved. This approach was used in testing for significance of differences between means for individual stations. However, the sampling design did not produce samples drawn at random from the regions. Consequently, the regional means which will be presented are not completely representative. However, they are the best estimates obtainable.

Technicians assigned to aging stations secured the following data from deer checked during open seasons, which occurred about December 1 each year: (1) sex (2) age, according to the Severinghaus (1949) technique (3) hind foot length, hock to tip of longest nail; measured to nearest 1/4 inch (4) antler beam diameter, one inch above the burr; measured to nearest 1/32 inch (5) antler beam length, burr to tip along outside curve; measured to nearest 1/2 inch (6) number of antler points (7) weight to nearest pound; plus a record of whether whole or dressed, and if dressed, the visceral organs remaining. In addition to these measurements, technicians collected ovaries from adult does whenever possible.

The ovaries were subsequently sectioned and examined for evidence of ovulation (see Cheatum, 1949). The weights, as recorded at field stations, were converted to represent the approximate weights of carcasses which had been bled and completely eviscerated. Weight conversions were made by reference to regressions presented by Severinghaus (1949a) and Hamerstrom and Camburn (1950).

The various measurements were tabulated into frequency distributions for individual sample areas for each sex and age class. Keysort punch cards were used in this process. Means and sums of squares of deviations were computed for most of the distributions.

Calculated coefficients of variation indicated that hind foot lengths exhibited much less dispersion than any of the other measurements taken. For example, the average coefficients of variation from a series of samples of yearling male deer were as follows: hind foot length, 4.3 per cent; hog-dressed weight, 16 per cent; antler beam diameter, 19 per cent; antler length, 29 per cent; and number of antler points, 34 per cent.

Hind foot length was less variable than other measurements taken in this study, and was more easily measured than total body length or height at shoulder. Because of these factors, hind foot length was selected as the primary criterion for comparing characteristics of deer in various parts of West Virginia.

This comparison consisted of testing for differences between means. The methods of analysis of variance and the "t" test were extensively employed. By use of these devices significant differences between mean hind foot lengths for aging stations were identified. The aging stations and the probable boundaries of regions exhibiting important differences are shown in Figure 1.

These boundaries divide the state into four regions. Each is more or less homogeneous in regard to mean hind foot length of

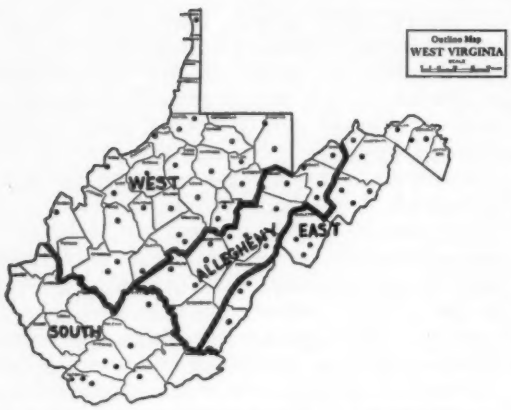

FIG. 1. Four contrasting regions of West Virginia, based on physical characteristics of deer. Locations of aging stations during one or more open seasons, 1951–54, are shown as black dots.

deer within it. There are significantly different minor areas within each region, but these areas are not contiguous. There is also some overlap between regions. For example, deer in the extreme northern part of the east region are similar in hind foot length to those in the southernmost part of the Allegheny region. However, the two areas are not similar ecologically. There would be no advantage in attempting to classify them together.

In Figure 1 the boundary of the south region is tentative since sampling from that region was of necessity limited to only five counties, and was not at all representative of the southwestern corner of the state. Deer are not numerous in that area and deer hunting has not been permitted in recent years.

REGIONAL CHARACTERISTICS OF DEER

HIND FOOT LENGTH—It can be seen that for each of the sex-age classes included in Table 1 there is a consistent relationship between regions. The longest hind foot lengths occurred in the west. Successively shorter foot lengths were observed in the Allegheny, south, and east regions. With few exceptions this ranking is repeated in all of the tables of other measurements which follow. The exceptions are in two of the characteristics for the south region.

BODY WEIGHT, HOG-DRESSED — Average weights shown in Table 2 reveal a consistent relationship between regions which corresponds to that shown by hind foot length. This is due to correlation between skeletal size and body weight. While the two elements are closely related, weight comparisons may be more easily visualized than hind foot length relationships.

Accordingly, a digression will be made to emphasize the variation in weights of deer within West Virginia. Average values shown in the tables do not indicate the extremes, of course. At the extremes it is evident that, by December, fawns in some parts of the west region average nearly twice as heavy as fawns in parts of the east region. Similarly fawns from the area where West Virginia's largest deer are found are actually heavier, on the average, than yearling deer from the section where the smallest animals occur.

To express this relationship in another way, it appears that variation in fall fawn weights within West Virginia is nearly as great as variation in such weights between the states of Maine and North Carolina. Shaw and McLaughlin (1951) state that average hog-dressed weights of fawns killed during open deer seasons in Massachusetts and Maine are about 66 pounds for males and 60 pounds for females. These weights are practically identical with those typical of the west region of West Virginia. At the other extreme, fawns from two of the middle-eastern border counties of West Virginia are

TABLE 1.—HIND FOOT LENGTH OF DEER FROM FOUR REGIONS OF WEST VIRGINIA
Data from legal kills, 1951–1954

	Age ½ Year				Age 1½ Years			
	Males		Females		Males		Females	
Region	No.	Mean	No.	Mean	No.	Mean	No.	Mean
West	680	16.91 in.	675	16.43 in.	435	19.00 in.	513	18.05
Allegheny	1180	16.20	1196	15.70	1120	18.39	1054	17.60
South	177	15.74	162	15.24	175	17.68	136	17.12
East	399	14.95	346	14.68	552	17.26	358	16.53

TABLE 2.—HOG-DRESSED WEIGHT OF DEER FROM FOUR REGIONS OF WEST VIRGINIA
Data from legal kills, 1951–1954

Region	Age ½ Year				Age 1½ Years			
	Males		Females		Males		Females	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean
West	560	66 lb.	568	61 lb.	436	105 lb.	417	91
Allegheny	723	57	707	53	674	97	691	87
South	158	50	136	46	150	83	116	73
East	346	44	282	43	451	79	295	72

similar in size to fawns in the Pisgah National Forest area of North Carolina (conversation with Frank Barick and K. J. Chiavetta).

Causes of the great diversity in size and weight of deer within West Virginia are not clearly understood. However, field observations indicate that the differences in size cannot be satisfactorily explained by differences in quantity of forage available during winter. That explanation has been used to rationalize differences in deer within some of the more northern states, notably Pennsylvania, New York and Michigan, where winter weather conditions are more severe than in West Virginia. Snow cover rarely persists in this state for longer than about one month. Conditions of continuous snow cover for much longer periods are common in New York and Michigan. As previously mentioned, there are no extensive overbrowsed areas in West Virginia.

ANTLER BEAM DIAMETER—Average antler beam diameters (Table 3) place the west, Allegheny, and east regions in the same relative order as do hind foot lengths and weights. However, the south region does not conform since its average antler beam diameter is smaller than that for the east.

TABLE 3.—ANTLER BEAM DIAMETER OF DEER FROM FOUR REGIONS OF WEST VIRGINIA
Data from legal kills, 1951–1954

Region	No.	Age 1½ Years Only	
		Mean (inches)	Mean (mm.)
West	463	0.80	20.3
Allegheny	1013	0.70	17.8
South	255	0.60	15.2
East	489	0.61	15.5

This inconsistency makes it appear that the relationship between antler development and either body weight or hind foot length is not the same in the south region as in the other three. Apparently bucks from the south region have antlers which are smaller in proportion to body size. As previously stated, however, the sample from this region represents a much smaller area than those for the other regions. Also a large portion of the sample is from an area which is exceptional in that it has recently been overpopulated with deer. Furthermore, the restocking in 1932 which ultimately produced the overpopulation was made with deer from Pisgah National Forest in North Carolina. A more complicated heredity may be involved.

OVULATION—Average ovulation rates (Table 4) also exhibit a departure from the ranking of regions which was established from hind foot lengths and body weights, averages for which place the south region intermediate between Allegheny and east. The same relationship does not hold for the average number of corpora lutea for either age class from the south region. However, ovulation rates for the other three regions fall into the usual order.

TABLE 4.—NUMBER OF CORPORA LUTEA IN OVARIES OF DEER FROM FOUR REGIONS OF WEST VIRGINIA
Data from legal kills, 1950–1953

Region	Age 1½ Years		Age 2½ Years and Older	
	No. Sets Ovaries	Mean No. C.L.	No. Sets Ovaries	Mean No. C.L.
West	84	1.77±.06*	128	1.90±.04*
Allegheny	154	1.34±.05	274	1.55±.04
South	15	1.27±.20	45	1.58±.10
East	85	1.29±.07	162	1.51±.06

* Standard error of the mean.

Table 4 includes the standard error of the mean for each ovulation rate. The samples are small and are not strictly representative of the regions but the standard errors given do provide a measure of dispersion in ovulation counts. If the samples for Allegheny, south and east regions did conform to the requirement of randomness, then none of the differences between their means would be significant at the 5% level. This fact emphasizes the caution which must be used in interpreting ovulation rates and indicates that the relationship between the south region and the other three is not necessarily as shown in Table 4.

It is much more difficult to obtain usable sets of ovaries than to secure hind foot length measurements. Since the latter measurement also has several advantages in regard to sampling error, it seemed practical to consider the possibility of a correlation between hind foot length and ovulation. This comparison was made using each deer season record which included both an ovulation count and a hind foot length for an individual doe. For yearling does only, the correlation coefficient was +0.24 (d.f.=313, .01 level = .148). For does of age 2½ years and older, +0.16 (d.f. = 550, .01 level = .115).

The low degree of association between the two variables indicates that one cannot be used to estimate the other within practical limits of accuracy. However, comparison of the two types of information collected from the same area or the same deer may help in detecting bias or unusual sampling error.

FAWN/DOE RATIO IN LEGAL KILL—According to the evidence from this index of rearing success, the four regions rank in the same order as on the basis of physical measurements. Rearing success is highest in the west region where the number of fawns in the kill actually exceeded the number of adult does (Table 5). Productivity is successively lower in the Allegheny, south, and east regions. Crude fawn/doe ratios indicate that in the east region does produce 1/3 less fawns than in the west.

AGE COMPOSITION OF ADULT SEGMENT OF LEGAL KILL—The age distribution of adult does in the kill is an index to productivity. Areas having relatively high productivity will have deer herds in which younger age classes are more predominant than in areas of low productivity. If mortality is more or less age-indiscriminate, then average age of adult does, and slope of the kill curve (Hayne and Eberhardt, 1952), will indicate the proportion of replacement to the deer herd (Gill, 1953a).

TABLE 5.—RELATIVE NUMBERS OF FAWNS AND ADULT DOES IN SAMPLES OF THE WEST VIRGINIA LEGAL KILL, 1951–1954

Region	No. Fawns Both Sexes	No. Does Age 1½ Years and Older	No. Fawns Per 100 Does
West	1615	1411	114
Allegheny	2600	3170	82
South	888	1131	78
East	851	1182	72
Total	5954	6894	86

In West Virginia the average age of legally killed adult does is lowest in the west region. Mean ages are successively higher in the Allegheny, south and east (Table 6). The differences in age structure between regions correspond to the pattern shown by hind foot length, body weight, and fawn/doe ratio.

TABLE 6.—AGE OF ADULT FEMALE DEER, 1½ YEARS OR OLDER, FROM FOUR REGIONS OF WEST VIRGINIA Data from legal kills, 1951–1954

Region	Number of Deer	Mean Age
West	1319	2.65 years
Allegheny	3185	2.91
South	451	3.09
East	1188	3.14
Total	6143	2.91

DISCUSSION

Three of the regions shown in Fig. 1 can be ranked in a definite order on the basis of all characteristics studied. In descending order of size and productivity of deer, these regions are: west, Allegheny, and east. The south region is intermediate between Allegheny and east with respect to hind foot length, body weight, fawn/doe ratio, and age composition. However, antler development in the portion of the south region which was sampled was inferior to that in the east region, and ovulation rate in the south region was not adequately determined.

Casual comparison of regional characteristics of deer with the general distribution of various physiographical areas in West Virginia does not reveal a good fit between characteristics of deer and any of several environmental conditions. These conditions include length of growing season, precipitation, soil parent material, known mineral deficiencies, calcareous deposits, slope, agricultural land capabilities, forest types, and others. Conversations with Drs. G. G. Pohlman and G. C. Anderson, respectively soils specialist and animal nutritionist with the West Virginia Agricultural Experiment Station, have led the writer to believe that the differences in deer characteristics between parts of the state probably are not attributable to any single ecological factor, but rather to a complex of factors.

The ecological variation within regions makes it impractical to attempt to identify these complexes at the regional level. Consequently, it would be preferable to investigate limiting environmental factors in reference to smaller areas. Individual aging station areas would be studied for this purpose. Known differences in deer characteristics between aging station areas constitute a logical basis for evaluating their relative range quality.

Information about variation in deer between regions has an obvious value in management of deer harvests. Currently, the primary harvest management objective in West Virginia is to obtain better distribution of deer kill throughout the open territory. An attempt has been made to improve hunter distribution through publicity rather than by restrictive regulations (DeGarmo; 1952b; Gill, 1953, 1954). Part of the publicity released in this effort has stressed the fact that the west region can support a greater percentage removal of female deer than the rest of the state. In the east region, where productivity is relatively low, sportsmen have been encouraged to hunt selectively for bucks in preference to does.

In general, knowledge of the variation in deer between regions has been useful in determining broad policies relating to harvest management.

ACKNOWLEDGMENTS

This investigation was originated and largely supervised by W. R. DeGarmo, formerly Leader of Deer Investigations in West Virginia. DeGarmo processed all ovarian material collected in 1951 and 1952. Later collections were interpreted by Arnold Schulz, who also made a statistical analysis of all ovulation data. This work was supervised by the writer.

Dr. Walter D. Foster, formerly biometrician with the West Virginia Agricultural Experiment Station, generously gave advice on some statistical problems. Valuable assistance in organization and review of the manuscript was supplied by Dr. George A. Petrides, of Michigan State College. This paper is part of the thesis requirement for the Master of Science degree at that institution.

SUMMARY

Size and productivity of West Virginia deer were studied under the assumption that these factors were related to range quality. Data involved sex, age, weight, skeletal size, antler development, and ovulation. The total sample included about 17,000 deer from legal kills for the period 1951 through 1954.

The state was divided into four regions, each having populations of deer with distinct characteristics. Deer were found to be largest and most productive in the west region. They were successively smaller and less productive in the Allegheny and east regions. South region deer were intermediate between those of the Allegheny and east in size and, probably, in productivity.

The causes of regional differences were not apparent. This problem requires additional study with respect to ecological differences between certain small areas in which deer characteristics are known.

Knowledge of the regional differences has been useful in determining harvest management policy.

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SOME BEHAVIOR CHARACTERISTICS OF MAMMALS USEFUL IN MANAGEMENT [1]

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There are several behavior characteristics among certain mammals that have been given inadequate attention, particularly from the standpoint of their having potential value in management. One of these is homing behavior, and another is the tendency for many individuals of certain species having restricted home ranges to remain in or close to the area where they were born, or where they have been held in captivity. The latter is considered in this paper to be a manifestation of homing behavior.

Homing in certain mammals has long been recognized. Familiar examples among domestic mammals are cats and dogs that returned home after having been released many miles away. Hamilton (1939) remarks that the homing instinct is "apparently well developed in most of our native mammals, for all species in which the trait has been studied exhibit a marked sense of direction." He found homing behavior well developed in eastern deer mice, red squirrels and eastern chipmunks. Mohr (1934) found that ear-tagged bats transported 30 miles from their roost readily returned. The Muries (1931) found homing well developed in western deer mice. Apparently this trait is more characteristic of some mammals than others, for Hamilton (*op. cit.*) claims it is not so well developed in the field mouse (*Microtus*) as it is in the deer mouse; and Linsdale (1946) believes that California ground squirrels ". . . are familiar with only the immediate surroundings of their homes and that they are poorly equipped to find the way back when transported outside that area."

C. M. Aldous (1937) made an important contribution to our knowledge of homing in the snowshoe hare when he published the results of trapping and tagging studies at the Station-on-Alexander, Minnesota. He states, "When the trapping and banding operations first started at the Station-on-Alexander in the fall of 1932, the captive hares taken from all the trapping stations were released at one common point known on the records as Green's Island. . . . Well over 100 hares were released here before the practice was discontinued in favor of releasing them at the point of capture. Although some of the hares lingered on the island, a great many of them made their way back to the place where originally they were caught. . . . Eighteen of the hares returned a distance of one mile or so, while 34, which was the largest number, returned one-half mile. It was from these two distances that most of the hares were taken from their home grounds to be released on the island. At the close of this practice of releasing on Green's Island many of the hares were taken three miles away and released, but none of these were ever recovered, so it is unknown whether any of them ever succeeded in returning. When released at one and one-eighth miles away, these hares had little difficulty in reaching their home grounds." Gillett (1934) found that snowshoe hares trapped, tagged, and then released three-eighths of a mile away from the point of capture returned easily to their homes.

Homing behavior in the California mule deer has recently been reported by Leopold *et al.* (1951), who state that ". . . every adult deer seems to have a highly specific and localized home range to which it returns each winter. Close observation of the deer arriving on the winter range indicates that each adult animal knows precisely where it is going and leaves the main trail (and the company of other migrating deer) at the most convenient point to reach its own customary wintering range." Furthermore,

[1] A contribution from Ohio Pittman-Robertson Projects 12-C, 80-D and 66-R. The author wishes to thank Dr. Charles A. Dambach and Paul Moore of the Ohio Division of Wildlife, Dr. E. H. Dustman, Leader of the Ohio Wildlife Research Unit, and W. A. Elkins of the U. S. Fish and Wildlife Service for critically reviewing the manuscript and making numerous valuable suggestions.

these workers ". . . are inclined to the belief that most Jawbone deer return regularly to habitual home range in summer just as they do in winter."

It is a common tendency for mammals which have been live-trapped in one locality and released in a strange habitat some distance away, to disperse quickly and randomly, often to considerable distances from the release point. A familiar example of this behavior is found in cottontail rabbits from Kansas released in Ohio; it happens even in rabbits taken in one county or township of Ohio and released in an adjoining county or township. Yet it appears that such animals, if held even temporarily in captivity on the release site, can be induced to remain on the area once they have been given their freedom. There is thus developed in individual animals, a "site affinity" or "areal affinity" for the place of release. Seton (1929) describes what appears to be a clear-cut example of this phenomenon in the snowshoe hare and the cottontail rabbit. He states, "In five or six cases, I had Cottontails and White-hares in a wire enclosure of about an acre. They were kept in for a month; then two large gates in their prison wall were thrown open, but they continued to haunt the same place as though still fenced in. If they chanced to run out of a gate, they would go butting their heads against the wire fence in their efforts to get back to their little home ground."

OHIO STUDIES

From 1922 to 1930, a total of 430 white-tailed deer were released in an 800-acre corral in the Theodore Roosevelt Game Preserve, a state-owned tract in Scioto County, Ohio. In succeeding years a few more deer were added to the corral, but during this period trees occasionally fell on the fence, breaking it down temporarily and permitting some of the deer to escape. In 1932, all of the deer, then believed to number about 1,000, were given their freedom. Prior to 1932 the escapees and their progeny were seen occasionally, but not to any extent outside of Nile Township where the corral was located. From 1935 to 1938 the writer was employed to make ecological studies in the Roosevelt Preserve; among his assignments was a study of the distribution and abundance of the white-tailed deer.

Utilizing a network of about 110 miles of CCC trucktrails and an additional 100 miles of state, county, and township roads, and driving his car approximately 1,000 miles per month over this territory, the locations of all observed deer were plotted on a map of western Scioto County gridded in one-square-mile (640 acres) sections. A complete picture of these day-by-day observations for the year 1937 is given in Figure 1. The

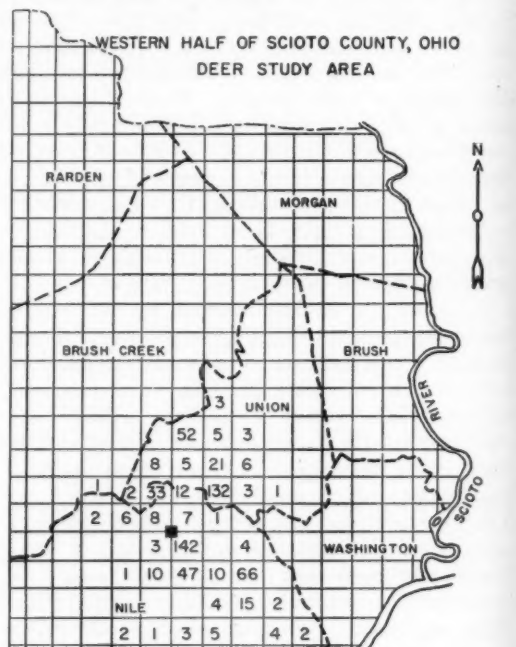

FIG. 1. Distribution of deer in Western Scioto County, Ohio, 1937, in relation to the corral from which they were liberated in 1932. The observation period covers a full year.

total number of deer observed that year was 640, all but two of which were recorded within a 5-mile radius of the corral. Of the 168 buck deer killed in 1943 in Scioto, Adams, and Pike counties, the only three counties open to hunting in Ohio's first modern deer season, 139 were known to have been taken within a 10-mile radius of the corral, either on private or state-owned land. Eleven years after the deer were lib-

erated from the corral it was evident that very few, including the progeny, had infiltrated the forest area beyond a radius of 10 miles; and most of them had not even strayed 5 miles from the point of release. The habitat within 20 miles of the corral can be described as homogeneous—principally dense stands of mixed pine and oak, with few openings.

The Roosevelt deer herd exhibited very strong areal affinity for the corral location and it is very doubtful if deer would have become established in Scioto County had the original group not been held for a time within this fenced area. Deer from this herd transplanted to Lawrence, Hocking, and Jackson counties, which have habitat similar to that of Scioto County, dispersed widely following release.

Officials of the Game Section of the Ohio Division of Wildlife have been interested in the possibility of restoring the snowshoe hare in portions of northeastern Ohio where it existed in some numbers in pioneer days. This thinking culminated in 1952 with the approval of a Pittman-Robertson project relative to this species; 200 live snowshoe hares from New Brunswick were stocked on the New Lyme Wildlife Restoration Area in Ashtabula county. The animals were released in a group and dispersal was immediate in all directions. After a month or so, none was seen again. In 1953, a 5-acre enclosure was constructed in the approximate center of the New Lyme Area, and 25 snowshoe hares from Wisconsin were released in the pen in January 1954. The New Lyme Area is characterized by swamp forest containing elm, black ash, red maple, pin oak, and swamp white oak. Although this cover type is prevalent throughout Ashtabula county, there is much farmland interspersed with the forest area.

An electrified wire was placed parallel to the top of the wire fence around the pen to exclude climbing predators, and pole traps were erected within the enclosure to exert some control over avian predators.

Tracks outside the enclosure a week or two after stocking indicated that some of the hares had escaped. Several young hares and two adults were live-trapped within the pen during the summer of 1954, and one live and one freshly killed adult were observed there in September. In the late fall of 1954 the gate of the enclosure was opened and remained open until December in order to permit the escape of the adults and their progeny.

In January 1955, an additional 25 snowshoe hares from Wisconsin were introduced into the pen. During census work on the area and surrounding it in January and February, 1955, Jesse B. Weaver and George E. Fennen, employees of the Ohio Division of Wildlife, found on one occasion the tracks of eight individual hares and on another occasion the tracks of three widely-separated individuals. Censusing was performed during several periods of deep snow. Since no tracks or other signs of hares could be found during the winter of 1953–1954, it is apparent that the tracks observed in early 1955 were those of hares which left the enclosure after the gate was opened in the fall of 1954 and/or escapees which survived and left the pen after stocking.

From this experiment it appears that the open release of 200 hares in the winter of 1953–1954 was a failure, but that the restoration attempt using a protected enclosure offers much promise of success. Here again is an instance of taking advantage of the areal affinity of a mammal reared or held in an enclosure, in a restoration effort.

For the past three years Ohio has had a Pittman-Robertson project in progress with the objective of determining factors limiting cottontail rabbit populations in eastern Ohio. Since soil conservation practices have become widespread in this section, much desirable appearing rabbit range has been created, yet cottontail numbers have continued to decline over a period of 25 years or more. In order to sort out factors believed to be responsible for the low cottontail population in eastern Ohio, a series of 5-acre fenced units was developed. These were constructed of 1-inch wire mesh and each was stocked with 5 pairs of tagged cottontail rabbits. A production of 18 rabbits to the acre was achieved in these pens.

At the end of 1952 and in succeeding years the annual production of rabbits within the pens has been released on the Woodbury Wildlife Area, Coshocton County, which surrounds the enclosures. A measurement of native cottontail population fluctuations on the Woodbury Area has been made annually since 1949, by means of live trapping. It was noted that the native cottontail population remained relatively stable from year to

year until 1953, the first year after the pen releases, when it increased by nearly 100 per cent. In the fall of 1954, after the second year's pen releases were made, there was a further population increase of 50 per cent over the preceding year. During the 1952 to 1954 period the county rabbit population, as revealed by hunter bag checks, remained very low (0.2 to 0.3 rabbits seen per hour of hunting effort). It appears that not only are the pen-reared rabbits stocked on the area exhibiting a strong areal affinity, but such stocking is overcoming a low density population threshhold as suggested by Leopold (1931), or an "extinction threshhold" as mentioned by Wing (1951). Dozens of Kansas and Missouri rabbits were stocked on the Woodbury Wildlife Area since it was acquired in 1934, but this practice had little, if any, effect on the native population, as measured by hunter success. Furthermore, the area has been improved for natural rabbit production by all of the techniques known to game managers; yet it failed to respond until after stocking with rabbits that were reared on the area.

MANAGEMENT APPLICATIONS

In Ohio, as in many other states, sportsmen groups, particularly rabbit hunters, have made an honest but misguided effort to improve their sport by importing and stocking rabbits from a group of midwestern states. Effort has also been devoted to transplanting rabbits from cities, orchards, nurseries and other areas of abundance to open hunting territory, with questionable results. States with public hunting grounds are also facing the problem of intensive hunting pressure, yet not enough rabbits are produced, even with expensive habitat improvement programs.

Gerstell (1935) propagated rabbits in open range pens but not extensively and economically enough for statewide stocking. However, it appears that use of areal or site affinity behavior in rabbits and other game mammals could be made by propagating them in pens on sportsmen's club grounds or public areas and releasing them in the immediate vicinity for the improvement of hunting. If site affinity behavior did not occur in rabbits, it would be far too expensive for clubs and state agencies to propagate them in pens, but since there is evidence of its existence, there is no valid reason why it should not be used to encourage local restoration efforts. Investigation of areal affinity of mammals capable of being reared in open range pens should be inaugurated at once, for even vanishing species of mammals might well be restored in favorable habitat by using the seminatural propagation-pen approach.

SUMMARY

Certain mammals that are propagated in an enclosure apparently develop a site or areal affinity for this area and upon release in its immediate vicinity, exhibit a remarkably slow rate of dispersal. The use of an open range type of seminatural propagation pen is suggested not only for further studies of this type of behavior in game mammals, but as a useful technique in local restoration of the species that exhibit site or areal affinity. In Ohio the use of a seminatural propagation enclosure resulted in the establishment of the Roosevelt Game Preserve herd of white-tailed deer. The method shows considerable promise in restoration programs for snowshoe hares and cottontail rabbits.

Seminatural propagation of rabbits in pens on sportsmen's club grounds and public hunting areas and the subsequent release of these animals to improve hunting on the area surrounding the pens appears to be entirely feasible. On a public hunting area in Ohio, extensive habitat improvements for cottontails and artificial stocking were carried on for years without appreciable effect on the low rabbit population present there. After stocking pen-reared rabbits produced on the area, the native cottontail population doubled. It is suggested that stocking of pen-reared rabbits on the area where they were raised, coupled with the apparent areal affinity of these animals, may overcome a low population density threshhold and permit a considerable increase in the local population.

Restoration of vanishing mammals which demonstrate areal affinity after release from propagation or holding pens might be achieved, at least locally, by using the seminatural propagation pen approach.

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RESULTS OF SPECIAL DEER HUNTS ON THE MUD LAKE NATIONAL WILDLIFE REFUGE, MINNESOTA [1]

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There were but few deer on the Mud Lake National Wildlife Refuge in northwestern Minnesota when the area was set aside as a federal waterfowl refuge on March 23, 1937. Two years later the population was estimated at 50 deer, and by 1940 the refuge manager guessed there were twice that number. Unlike most deer herds the population did not increase in typical irruptive form. Instead it built up slowly to 1,300 deer in 1949.

A comprehensive browse survey in April 1949 by state and federal personnel showed the need for opening the refuge to deer hunting. In November 1949 the first controlled hunt was held, followed by similar hunts in 1951, 1952, 1953, and 1954 (no open season in 1950).

The objectives of this study were to measure the effect of the hunts on weight, sex ratio, productivity, and age composition of the population and to determine if possible how these physical characteristics might tie in with the rate of increase.

[1] The writers are indebted to the following persons for field assistance: F. B. Lee; N. J. Ordal; Robert Farmes; Lester Magnus; V. E. Gunvalson of the Minnesota Division of Game and Fish, P-R Project 11-R; R. W. Hunt of the U. S. Fish and Wildlife Service and students in Wildlife Management at the University of Minnesota.

The 93 square-mile refuge is located in Marshall County about 42 miles from the Canada border and 54 miles from the North Dakota line. It lies in the bed of Glacial Lake Agassiz in the narrow transition zone between the prairie and the coniferous zone. Important cover types include the willows and trembling aspen although there are patches of coniferous swamp and upland hardwood. About one-third of the refuge consists of open water and marshes, and the rest may be regarded as potential deer range. Hunt and Mangus (1954) have described the refuge in more detail.

POPULATION BEHAVIOR

Because the Refuge deer move freely between the Refuge and adjacent territory, they must be regarded as part of the local deer population. For this reason it seems important to explain occurrences on the refuge against a background of what has happened to the deer outside the area. Starting in 1936 all of Marshall County, including the area which became the Mud Lake Refuge in 1937, was open to deer hunting. Since then there have been annual county seasons except in 1939, 1941, and 1950. The refuge was open to deer hunting for the first time in 1949. County kill statistics, based on hunters' reports, are avail-

able for the period 1945 to 1954 and show that the harvest ranged from 537 to 1,049 and averaged 763 deer. This is a minimum report because it is known that only about 25 per cent of the hunters annually send in their report cards.

On the refuge the herd responded to protection, but it did not increase as fast as herds on other protected areas such as the Necedah Refuge in central Wisconsin (Martin and Krefting, 1953) or the Tamarac Refuge in northwestern Minnesota (Krefting *et al.*, 1955). The Mud Lake Refuge deer population fluctuated over the years 1939 to 1954, partly because of hunting removals during the latter half of the period (Figure 1). The population estimates presented up to 1946 are based on guesses by those familiar with the area, particularly refuge managers. Starting in 1947, the estimates are based on airplane counts and are believed to be reliable.

From a few deer in 1937 the herd increased so that by 1946 the population was estimated at at 600 and by 1949 it reached 1,300. No satisfactory explanation can be given for the slow increase in the population, but it seems logical that losses due to severe spring floods, winter mortality due to the lack of good winter cover, and the influence of burning on the habitat were important limiting factors. In the summer of 1937 and the spring of 1938 the refuge area was subjected to one of the worst floods since 1919. Again in the spring of 1941 much of the area was flooded. In June of that year the refuge manager's report states, "Deer moved from the outlying swamp areas back to the refuge in the spring, but due to the increasing water levels, left the refuge in considerable numbers and are not as numerous as in the past year." A similar high water situation developed again in the spring of 1945 and the manager reported, "The increase in deer population by the production of young has been offset by the number which moved to higher grounds outside the refuge area during the periods when the water levels were high." In 1950 from April 1 to May 15 the refuge and surrounding area were again subjected to one of the worst floods in refuge history. On the basis of strip surveys and

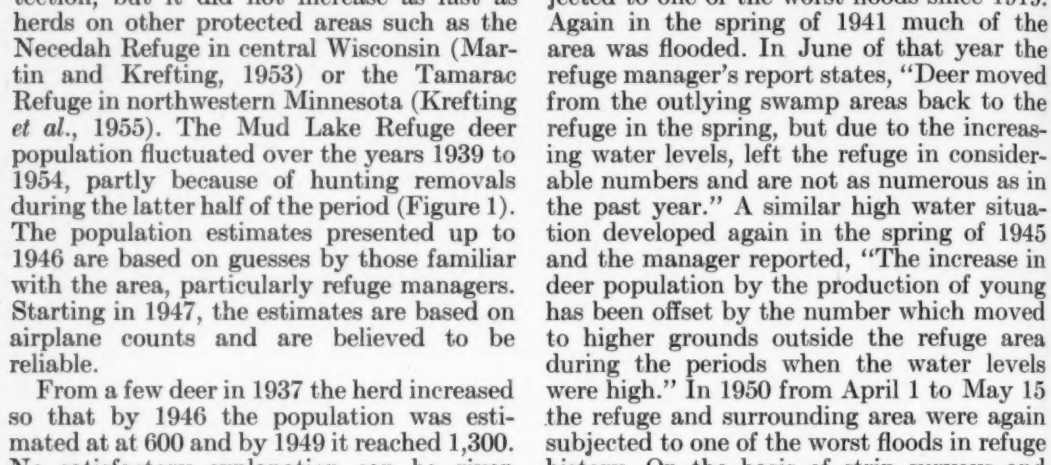

FIG. 1. ------ POPULATION AND KILL 1939–1954

general coverage the refuge flood loss was estimated at 100 deer.

Information on winter mortality as reported by Hunt and Mangus for the period 1947–1951 shows that the annual losses ranged from an estimated 16 to 110 deer. No data are available prior to 1947 although it seems logical to assume that losses occurred at least during severe winters. For example, in March 1939 the refuge manager reported that the snow depth was five feet on the level. Also in March of 1943 and 1950 the refuge was covered by very deep snows. During the severe winters the hardwood and aspen groves probably furnish the best cover. Some of the taller and denser stands of willow provide cover as well as food. In general, however, good winter cover is inadequate.

Particularly large fires burned over parts of the refuge in 1944, 1946, 1947, and 1952. These fires tended to reduce the amount of winter cover temporarily but later they also served to increase the food supply by stimulating new sprout growth.

STATUS OF FOOD SUPPLY

Mud Lake Refuge represents a special problem. Until sufficient research has been done on the nutritional value of the woody and non-woody plants, the food situation will not be clearly understood. As early as October 1940 the refuge manager had become alarmed about the winter food supply and wrote in his report, "Winter food for these animals is soon going to be a problem." Six months later (April 1941) his report stated, "The swamp areas have been heavily browsed and the food situation may become acute within a few years if the population increases in the same proportion as it did in the past." Apparently the anticipated food shortage did not develop as the manager's report for August 1944 revealed, "The food situation is good. Periodic inspections revealed an abundance of such species as dogwood, young willows, young aspen, bog birch, and elder."

In April 1949, the first comprehensive deer browse survey was made by state and federal personnel and reported on by Krefting and Lee (1949). The range appraisal method described by Aldous (1944) was used since it was best adapted for the study. The system consisted of selecting an adequate series of 1/100-acre plots on which are estimated the density (each plot represents 100 per cent and the density is that percentage of the plot area covered by the vegetation) and the degree of browsing (percentage of the annual growth taked within reach of deer, *i.e.*, 7 feet). Field data on vegetation density and browse use by deer were obtained by appraising 725 such plots. A restricted random sampling was used and the refuge was subdivided into eight units, half of which were winter concentration areas. Only woody plants were tallied although non-woody plants were recognized to be important.

For the winter concentration areas the bulk of browse plants consisted of willow species (*Salix* spp.) as a group. Although the deer showed preference for some kinds of willows others were browsed lightly or not at all. Willows, however, were considered as a unit because of the difficulty of differentiating species. If the willows could have been considered by species rather than as a group, certain willows would definitely have been overbrowsed. In two of the four winter concentration areas the willows as a unit received fairly excessive browsing. Also balsam poplar (*Populus balsamifera*) and red osier dogwood (*Cornus stolonifera*) were overbrowsed while aspen (*Populus tremuloides*) was not overbrowsed.

In only one of the four units was willow overbrowsed, but the results for the four units as a whole showed that browse production exceeded consumption by a considerable amount. Also aspen did not receive excessive use but red osier dogwood, balsam poplar, and bog birch (*Betula pumila*) were overbrowsed.

HUNTING SEASON RESULTS

NUMBER OF HUNTERS AND KILL. All hunting was done on a first-come-basis and no limitations were placed on the number of hunters.

In 1949, on opening day, 400 hunters were tallied at checking stations. The special five-day season opened without snow, and hunting conditions remained poor until a light snow fell on the last day. An estimated 800 individual hunters were on the refuge that year, and the season kill for the 20,000-acre open area was 450 deer, or 33 per square mile. Success of the hunters ranged from 31 per cent the first day to 9 per cent the last day. For the season 56 per

cent of the hunters were successful. Eighty-three per cent of them resided in counties in the refuge area. Total hunter days was calculated at 2,887.

In contrast, the 1951 season opened with 7 inches of wet snow on the ground. Snow clung to the vegetation, and visibility was extremely poor until the ninth day. Temperatures, likewise, were not conducive to good hunting. Daily minimum temperatures ranged from −17° to 17°F. On opening day, 835 hunters were counted; they bagged 144 deer. The season kill was 370 deer and 31 per cent of an estimated 1,200 individual hunters were successful. Eighty per cent of the successful hunters resided in counties adjacent to the refuge. Total hunter days was calculated at 3,237.

The 1952 season opened with poor hunting conditions and was similar to 1949 in many respects. Lack of rain and snow the first two days made it difficult to hunt without making a great deal of noise. A rain on the third day changed to snow and on the fourth day there was one inch of tracking snow on the ground. By the eighth day most of the snow had disappeared. On opening day 579 hunters were attracted to the refuge and they killed 93 deer. During the nine-day season an estimated 1,100 hunters bagged 222 deer. Estimated hunter success was 20 per cent and 77 per cent were from the refuge area. Total hunter days was calculated at 2,028.

In 1953, the season opened without snow and "bluebird" weather was encountered during the three-day special season. Temperatures were slightly above the freezing point. Six hundred fifty-four hunters came to the refuge the first day. They bagged 71 deer for a success of 21 per cent. For the season an estimated 750 individual hunters killed 220 deer for a success of 29 per cent. Sixty-nine per cent lived in the counties in the refuge area. Total hunter days was calculated at 1,704.

The 1954 season opened a week later than usual (November 20) and "bluebird" weather similar to the 1953 season was encountered. There was no snow on the ground and the temperatures were slightly below freezing. Snow fell shortly after the three-day season closed. On opening day 826 hunters bagged 147 deer for a success of 18 per cent. During the season an estimated 900 individual hunters killed 208 deer for a success of 23 per cent. Sixty-seven per cent resided in the counties in the refuge area. Total hunter days was calculated at 2,203.

DRESSED WEIGHT OF DEER. During the five hunting seasons, weight information was secured on 1,294 deer—278 female fawns, 294 male fawns, 393 does, and 329 bucks (Table 1). Analysis of the weight data shows the average weight of the adult bucks decreased by 30 pounds. Weights of does showed significant increases and decreases the first three seasons and about the same weight the last season. The fawns showed similar weight increases and decreases the first four seasons.

No complete explanation can be given for the 30-pound reduction in the average weight of the adult male deer (185 to 155 pounds). It may be due in part at least to the gradual removal of the heavy older deer by hunting and possibly the loss due to the 1950 spring flood. A similar but less severe weight reduction was noted on the Tamarac Refuge after the third open season (168 pounds in 1951 and 157 pounds in 1953).

TABLE 1.—AVERAGE DRESSED WEIGHT OF DEER (POUNDS)[1]

	All Fawns		All Yearlings and Adults		Weight by age classes													
					1½		2½		3½		4½		5½		6½		7½	
Year	Male	Female	Male	Female	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1949	72*	67*	185*	131*	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1951	80*	74*	169*	136*	119	120	162	138	180	132	...	144	...	134	...	137	...	142
1952	75*	73	161*	128*	133*	120	138**	127*	249	144**	236	153	...	121	...	165*	237	...
1953	81*	77**	159	128	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1954	83	74	155	130	...	...	...	...	...	...	...	...	...	...	...	...	...	...

[1] Viscera removed but often the liver and heart remained in the carcass.
* Significant at 1% level.
** Significant at 5% level.

The increase in fawn weights from 1949 to 1951 (8 pounds for males and 7 pounds for females) may be the result of more healthy does being able to produce larger offspring. Also the improved summer and fall range may have been responsible for the increased weights after the first open season. However, the increases and decreases in the fawn weights after 1951 are not explainable. Possibly the earliness or lateness of the birth period each year may have an influence on the fawn weights at hunting time.

FAWN PRODUCTIVITY AND SEX RATIO. The fawn per adult doe ratio has been used as an indicator of fawn productivity in a number of parks and refuges in Minnesota where special controlled hunts have been held. In these areas the number of fawns per doe increased steadily during the successive hunting seasons. On the Tamarac Refuge, Krefting *et al.* (1955) found the number of fawns per 100 does increased from 70 to 77 after three open seasons (1951–1953). For the Mud Lake Refuge it is important to note the ratio was 142 fawns per 100 does when the refuge was first hunted in 1949 (Table 2). This high fawn productivity level

TABLE 2.—SEX RATIO AND FAWN PRODUCTIVITY

	Per cent of Kill		Fawns per doe ratio	Sex Ratio—Males : 100 Females		
Year	Fawn	Adult	Fawns : 100 Females	Fawn	Adult	All Deer
1949	43.6	56.4	142 : 100	81 : 100	83 : 100	82 : 100
1951	45.6	54.4	136 : 100	113 : 100	64 : 100	83 : 100
1952	42.0	58.0	144 : 100	98 : 100	97 : 100	97 : 100
1953	47.9	52.1	179 : 100	165 : 100	94 : 100	123 : 100
1954	41.4	58.6	141 : 100	108 : 100	100 : 100	103 : 100

was also maintained for the other open seasons (1951–1954).

Sex ratio data on adult deer showed the females exceeded the males by a considerable amount in 1949. However, it is important to note that after five hunting seasons the ratio became equal for the adults and for the fawns the males slightly outnumbered the females.

RELATION OF HUNTING TO AGE. In 1949 the only information obtained on age was for the adult bucks, and it was based on the beam diameter measurement method described by Cahalane (1932). Measurements on 91 bucks showed 20 per cent in the 1½-year age class, 15 per cent 2½-years old, 30 per cent 3½ and 4½-years old, and 35 per cent 5½-years and older. These data show that most of the buck deer were quite old. In 1951 and 1952 the age of the deer was determined by the use of the replacement and wear of the teeth method described by Severinghaus (1949). Age information in 1951 has shown the per cent kill by age classes followed the usual pattern with the exception of the slight weakness of the 3½-year age class (Table 3). Also the

TABLE 3.—DISTRIBUTION OF KILL BY SEX AND AGE CLASS (PER CENT)

	Male		Female		All Deer	
Age—Years	1951	1952	1951	1952	1951	1952
½.....	21.3	20.1	22.0	21.4	43.3	41.5
1½.....	7.8	17.6	7.8	18.2	15.6	35.8
2½.....	4.3	3.1	11.3	4.4	15.6	7.5
3½.....	1.4	1.3	7.1	5.6	8.5	6.9
4½.....	...	3.8	10.6	1.8	10.6	5.6
5½.....	...	...	4.3	0.7	4.3	0.7
6½.....	...	...	0.7	1.3	0.7	1.3
7½.....	...	0.7	1.4	...	1.4	0.7
Average age of herd (years)	1.1	1.5	2.5	1.7	2.0	1.6
Average age of adults —2½ years and older	2.7	3.9	3.9	3.7	3.8	3.8

1½-year class was not as strong as might be expected. The apparent weakness in the 1½-year-old group may be the result of a heavy loss among the fawns born in the spring of 1950. The refuge had losses due to the spring flood, and over much of the state the fawn loss was quite severe during the 1949–50 winter. The 3½-year class may also reflect a loss among the fawns born in the spring of 1948.

In 1952 the 1½-year-old deer showed up very strong in the kill and probably reflects the heavy fawn crop of 1951. Although the 1½-year age class was only slightly weak in 1951, it showed up as a very weak 2½-year class (7 per cent) in 1952.

Since none of the deer was aged by the tooth wear method in 1949, it was not possible to determine the average age of the herd based on the kill of 450. In 1951 (season

closed in 1950) the average age of the Mud Lake herd was two years and in 1952 this was reduced to 1.6 years. The average age of all male deer was 1.1 in 1951 and 1.5 years in 1952. This increase (.4 year) resulted from a larger number of 1½-year olds and also older deer being killed in 1952. Apparently the hunting pressure of 1951 was not great enough to remove the older bucks. Data on the female deer showed the average age decreased .8 year (2.5 to 1.7) from 1951 to 1952. Also the average of all adult deer 2½-years and older remained the same both years (3.8 years).

Although it is assumed that the age classes of the deer killed are representative of the living population, this may not be the case. Some of the variables which could influence age class sampling are: differences in vulnerability of age classes to hunting; mis-aging, especially between the 1½ and 2½-year classes; weather, particularly the presence or absence of snow; hunter selectivity of sexes and certain age groups; and length of open season. At Mud Lake the 1951 and 1952 seasons were the same length (9 days) but there was considerable snow for the 1951 season and none in 1952.

SUMMARY AND CONCLUSIONS

1. Prior to opening the Mud Lake Refuge to hunting in 1949, estimates placed the deer population at 50 deer in 1940; 350 in 1945; and 1,300 in 1949. Unlike most deer herds the population did not increase in typical irruptive form as a result of the protection given. Apparently the heavy kills outside the refuge, winter mortality, and losses due to spring floods were the major factors that kept the herd in check.

2. Checking stations were operated to obtain information on weight, sex, age of deer, and residence of successful hunters.

3. The 93-square-mile refuge has been open to hunting with firearms five times (1949 and 1951–1954, inclusive). Each year about 20,000 acres or half of the refuge deer range has been open to hunting.

4. The quota was set at 600 deer in 1949 and 450 were killed. No quota was used for the rest of the open seasons (1951–1954, inclusive) and an additional 1,020 deer were harvested. During the five open seasons an estimated 4,750 hunters bagged 1,470 deer. Hunter success ranged from 20 to 56 per cent and averaged 31 per cent for the five-year period.

5. Fawns made up 42 to 48 per cent of the kill. Also fawn productivity ranged from 136 to 179 fawns per 100 does.

6. The sex ratio showed an excess of females among both fawn and adult deer the first open season. After that the sex ratio tended to become more even for both age groups.

7. Average dressed weight data on 1,294 deer have shown the following changes: the adult bucks decreased from 185 to 155 pounds; the adult does weighed about the same (130 pounds); and both sexes of fawns showed significant weight differences of three to eight pounds the first four seasons.

8. Deer were aged by the replacement and wear of the teeth method in 1951 and 1952. In 1951 the data showed a weakness in the 1½-year-old class and a fairly strong 2½-year class. For 1952 the 2½-year class appeared as weak while the 1½-year class was strong. Also the average age of the herd was reduced by .4 year (2.0 to 1.6 years) while the average age of adult deer (2½-years and older) remained the same (3.8 years).

9. Residents of Marshall County and other counties in the refuge area killed about three-fourths of the deer.

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RELATIONSHIPS BETWEEN THE CHEMISTRY OF MINNESOTA SURFACE WATERS AND WILDLIFE MANAGEMENT

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Introduction

Relationships between chemical quality of fresh waters and associated geological, climatic, and biological phenomena have long been of interest to aquatic biologists. Minnesota is especially favorably located for such observations because of varied climate and geology and a resulting wide range in the chemical quality of surface waters. Studies of regional water chemistry of Minnesota lakes have been carried out in Minnesota since 1935 and, as has been reported earlier (Eddy, 1938; Moyle, 1945), patterns of water chemistry are evident that are associated with biological patterns. The relationships noted are general and geographic in nature and should be applied with caution to individual waters. Water chemistry is only one of many factors which affect the productivity of lakes.

Most of the chemical and biological data presented were gathered on routine surveys of fish lakes, waterfowl lakes, and prospective fish-rearing ponds from 1940 through 1951. In all, 1,546 water analyses are considered. Biological data for fish lakes and ponds were gathered by the Fisheries Research Unit of the Minnesota Department of Conservation and data on waterfowl lakes by the Pittman-Robertson Game Research Unit. As here considered, "fish lakes" are lakes deeper than 10 feet which are known to have game-fish populations, waterfowl lakes are fairly large lakes that are shallower than 10 feet, and ponds are small shallow bodies of water.

Methods and Limitations of Chemical Analyses

In the series of analyses considered, total alkalinity (carbonates), sulphates, and chlorides were determined in order to ascertain general water quality and determinations for phosphorus and nitrogenous compounds were made in order to obtain an indication of water fertility. Analyses for other substances were occasionally made.

The water samples were collected in summer and were taken, unless otherwise specified, from the surface and in open water of natural and uncontaminated lakes and ponds. Analyses were usually made within two or three days after the collection of samples. Except as otherwise noted, analytical procedures used were those of Standard Methods for the Examination of Water and Sewage (Am. Pub. Health Assoc., 1936) with some modifications to fit local conditions. Phosphorus was determined by the modified Deniges method of Taylor (1937). Low concentrations of sulphate ion (below 10 ppm) were measured turbidimetrically; through 1948 colorimetric determinations were made by ocular comparison with freshly prepared standards but beginning in 1949 a Coleman spectrophotometer was used. Total nitrogen, as here considered, is the sum of nitrate, nitrite, and Kjeldahl nitrogen (ammonia and organic) each of which was determined separately. It is likely that nitrogen concentrations recorded for some of the more fertile southern Minnesota waters are too low. Recent work by Mr. John Dobie of our laboratory suggests that the digestion procedure given Kjeldahl nitrogen in Standard Methods is not entirely adequate for organic nitrogen in highly fertile waters. It should be understood that total nitrogen and total phosphorus as considered here includes all nitrogen and phosphorus in the unfiltered samples.

No preservative was used in most of the samples and since chemical changes may occur in samples because of bacterial action, affecting especially such unstable substances as soluble phosphorus and nitrites, the analytical results must therefore be regarded as approximate.

Factors Which Influence Water Chemistry

A chemical analysis of a sample from any natural body of water gives but a momentary picture of conditions within that body

of water. Within certain limits, the chemistry of any water is continually changing and a single analysis can be considered a temporary resultant of many continuously interacting factors. These factors are of three general types; (1) those related to the chemical and physical nature of the watershed and lake bed, (2) those related to water supply and loss, and (3) those related to the complicated biological and chemical system within the water itself. Over a long period of time even the basic chemical nature of a lake may change, but from the short-term point of view, the variations in water chemistry can best be considered as fluctuations around a mean and within a limited range.

Geology and soils exert great influence on the chemistry of waters. Nearly all ions and many of the compounds in waters are carried in from the surrounding lands by surface or ground waters. The exceptions are nitrogtenous compounds which may be fixed in he water by bacterial action or, in case of ammonia, be added with rain. Some important physiographic and hydrographic features affecting water chemistry in Minnesota are shown in Figures 1 through 4. In the northeast, igneous and metamorphic rocks are exposed. Here lake waters have a low concentration of readily soluble substances, and lakes are often of the oligotrophic type. Part of central Minnesota is overlain with red (Patrician) glacial drift. This red drift, as pointed out by Thiel (1933), contains less lime than the gray drift which covers much of the rest of the state. But because the red drift contains much gravel and sand, lime readily leaches from it and forms marl deposits in lakes. The present series of analyses show that waters in the red drift are poorer in nitrogen and phosphorus than those of the gray drift, but are richer than those of the igneous rock region. Highest concentrations of dissolved salts are found in southwestern Minnesota where the gray drift overlies and incorporates Cretaceous rock formations. The waters here have high concentrations of carbonates, sulphates, and chlorides and are usually also rich in nitrogen and phosphorus. Lakes located between these two geographical extremes of the state tend to have waters of intermediate quality. Similar observations have been made by Rawson (1951) for Canadian waters.

Precipitation and evaporation also influence water chemistry. In Minnesota, precipitation varies from 20 inches a year in the northwest to 32 inches a year in the southeast and runoff ranges from less than an inch a year along the Dakota border to more than 10 inches near Lake Superior (Prior, 1949). Lakes in the northeast receive an abundance of water and usually have active outlets; chemical constituents in their waters are being continually diluted and lost with the water flowing from them. In contrast, lakes in the southwest are often landlocked or have intermittent outlets that function only during wet years. In such waters, salts accumulate. Rate of evaporation from open water surfaces has an important effect in concentrating salts. According to Meyer (1942), evaporation from open water surfaces exceeds the rain that falls on them by about 10 inches a year in southwestern Minnesota but in the northeast, rainfall on open water surfaces exceeds the evaporation by about 10 inches a year.

In general, lakes become shallower across the state from northeast to southeast. This is an expression both of their origin and the fact that eutrophication and filling has proceeded more rapidly in the fertile southern lakes than it has in the less fertile northern lakes. From the point of view of lake management, the proportion of fish lakes decreases from northeast to southwest, and the proportion of waterfowl lakes increases. Thus, in the northwest (Areas 1 and 2, Fig. 5), 70 per cent of the lakes from which water samples were received were fish lakes; in the southwest (Areas 6 and 9, Fig. 5), only 17 per cent were fish lakes. This trend in lake depths also influences the water chemistry, for shallow lakes and ponds have a greater area of bottom in proportion to their volume than deep lakes, and are therefore likely to receive more salts by diffusion from the bottom soil.

The biological and chemical processes, reactions, and interrelationships in waters are complicated and often not well understood. Those that influence water chemistry are of three general types: (1) changes associated with variation in carbon dioxide, such as changes in carbonate content, fluctuations in pH, and differences in the solubility of phosphates; (2) changes brought about by the oxidation, reduction, or breakdown of elemental substances and com-

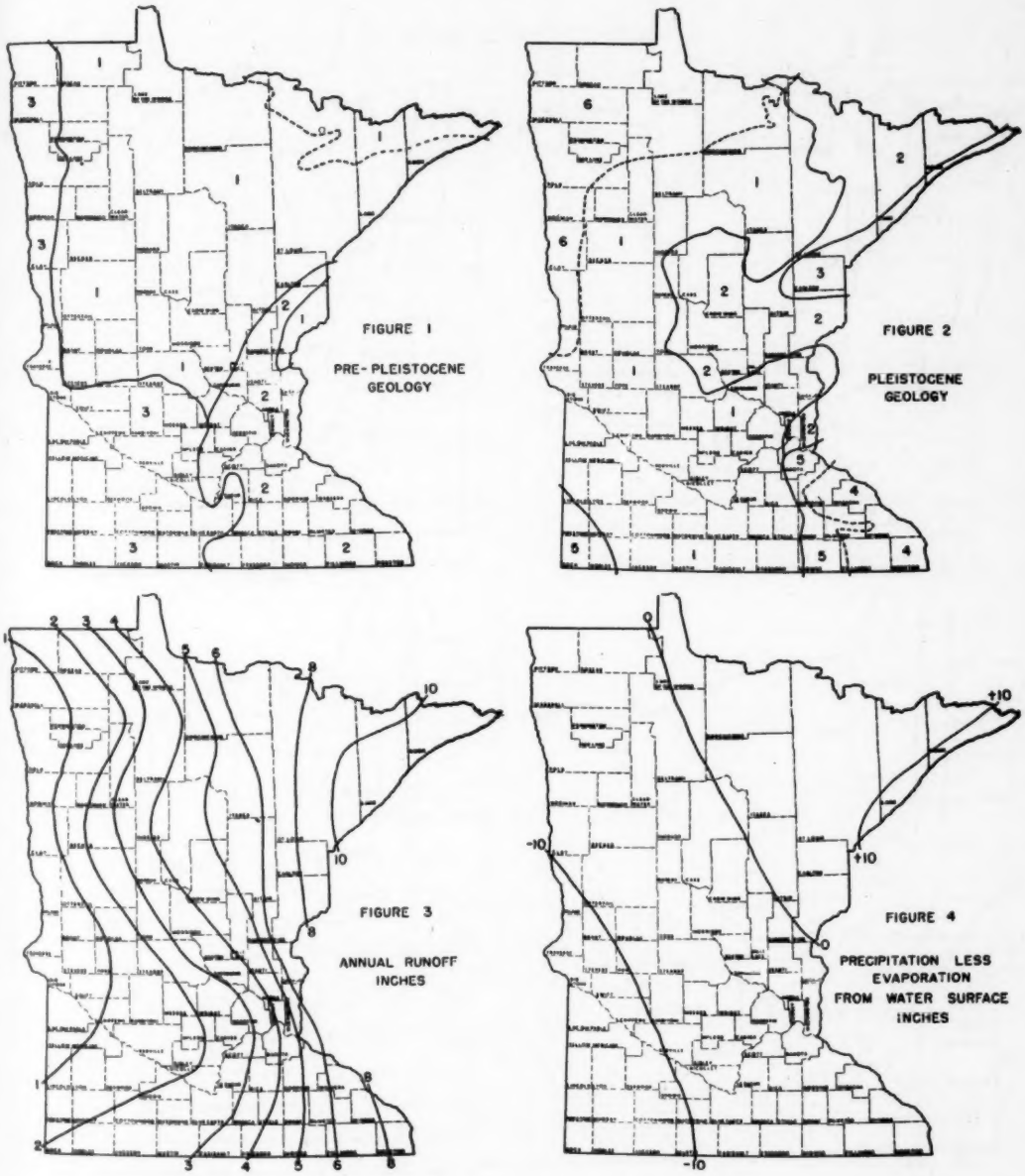

FIG. 1. From U. S. G. S. data. 1—Pre-Cambrian igneous and metamorphic rocks; 2—Paleozoic sedimentary rocks. 3—Cretaceous sedimentary rocks. FIG. 2. From U. S. G. S. data. 1—Gray drift of Wisconsin glaciation; 2 and 3—Lobes of red drift of Wisconsin glaciation; 4—Driftless area; 5—Pre-Wisconsin drifts; 6—Bed of glacial Lake Agassiz. FIG. 3. From Prior, 1949. FIG. 4. From Meyer, 1942.

pounds, both organic and inorganic, such as fixation of nitrogen, precipitation of reduced iron, and breakdown of proteins; and (3) changes brought about by the accumulation of elements and compounds in plant and animal matter.

It is evident, both from the foregoing considerations and from series of analyses from the same body of water, that any single analysis can supply only indicative information. In an attempt to minimize variation, water chemistry has been con-

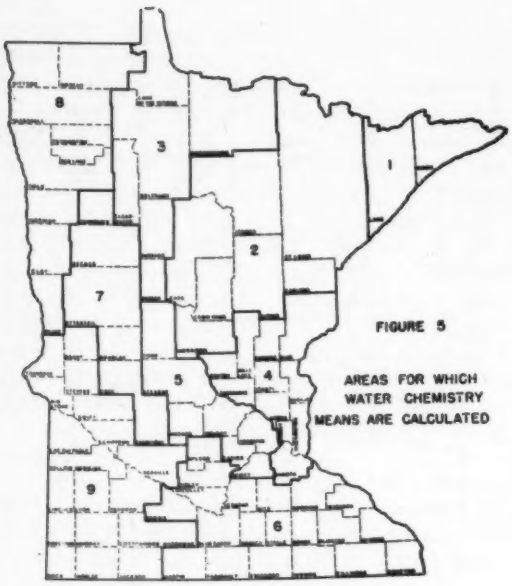

FIGURE 5

AREAS FOR WHICH WATER CHEMISTRY MEANS ARE CALCULATED

FIGURE 6

TOTAL ALKALINITY P.P.M.

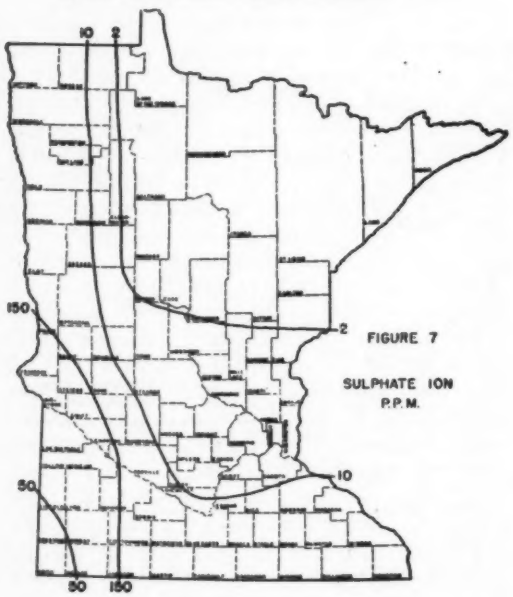

FIGURE 7

SULPHATE ION P.P.M.

FIGURE 8

CHLORIDE ION P.P.M.

FIG. 5. Areas of similar water quality arranged in order of increasing salinity. FIGS. 6 to 8. Isolines of some chemical components of surface waters. See text for explanation.

sidered on a regional basis and means and medians of fairly large series used. Of these two kinds of averages, the median appears to be most representative of usual conditions in lakes of the series. The mean tends to be influenced by analyses from a few bodies of water in which salt concentrations are usually high or low. Except for analyses for total alkalinity, the means of series are usually somewhat larger than the medians.

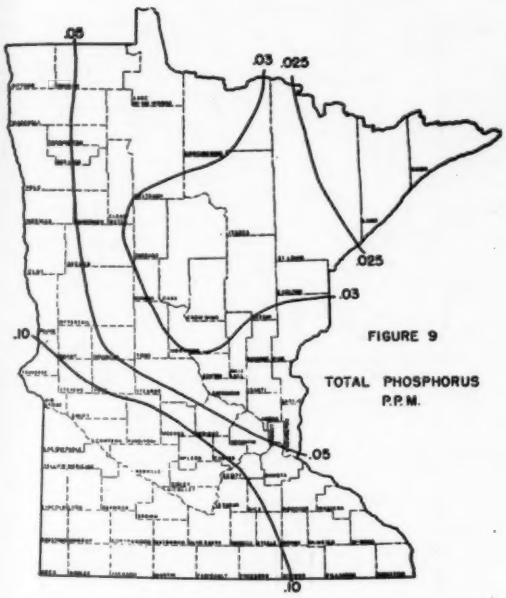

FIGURE 9
TOTAL PHOSPHORUS P.P.M.

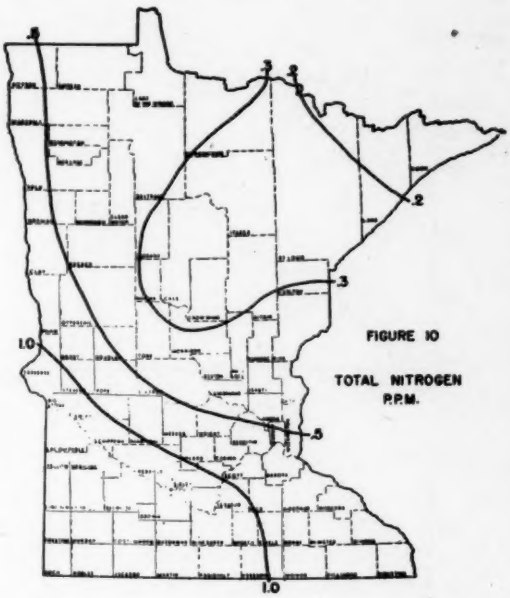

FIGURE 10
TOTAL NITROGEN P.P.M.

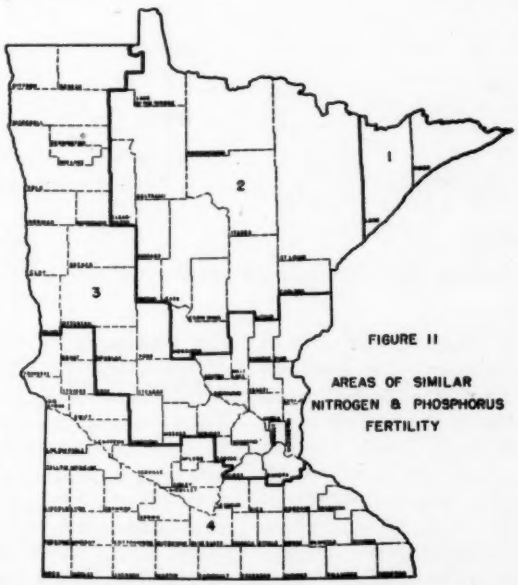

FIGURE 11
AREAS OF SIMILAR NITROGEN & PHOSPHORUS FERTILITY

FIGS. 9 and 10. Isolines for concentrations of total phosphorus and total nitrogen in surface waters. See text for explanation. FIG. 11. Areas of nitrogen and phosphorus fertility of surface waters arranged in order of increasing fertility.

REGIONAL WATER CHEMISTRY OF MINNESOTA

Before discussing individual elements and compounds, it would be useful to consider an over-all and general picture of the regional surface water chemistry of Minnesota. In the 1,546 analyses considered, the range of chemical constituents is as follows:

	Parts per Million	
Total alkalinity	6.3	537.5
Sulphate ion	0.0	1,210.0
Chloride ion	0.0	113.0
Total phosphorus	0.002	1.6
Total nitrogen	0.06	5.9

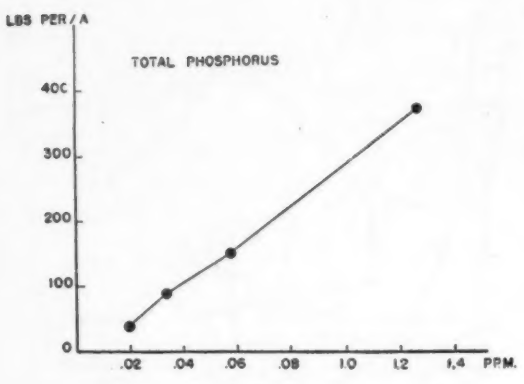

FIGURE 12

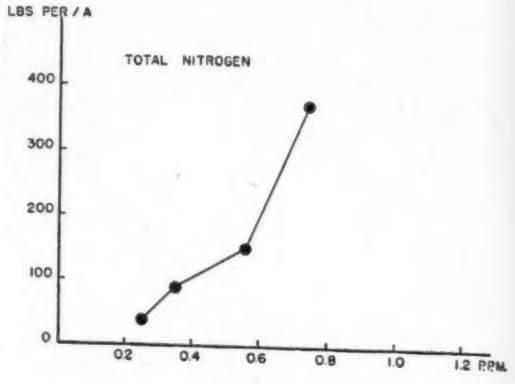

FIGURE 13

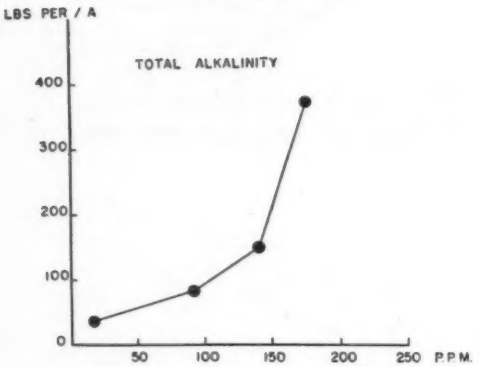

FIGURE 14

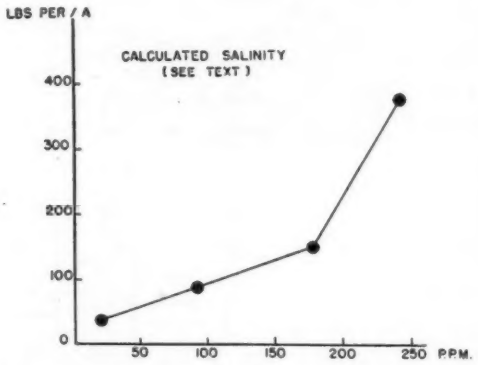

FIGURE 15

FIG. 12–15. Nature of relationship between water quality and carrying capacity of lakes for fish.

To show the general regional patterns of water chemistry, the analyses were grouped by counties and medians of the county series determined. These medians were plotted on state outline maps and approximate isolines of concentrations drawn in free-hand. Such representations of most usual concentrations of total alkalinity, sulphate ion, chloride ion, total phosphorus, and total nitrogen are shown in Figures 6 through 10.

A general increase in the grosser chemical constituents of water (carbonates, sulphates, and chlorides) from northeast and southwest will be observed from these figures. The fertility of waters as shown by phosphorus and nitrogen is related to the total concentration of dissolved salts but this relationship is not a straight line and shows much variation in individual waters. On the basis of nitrogen and phosphorus, waters of the state seem to fall into four general groups: (1) northeastern Minnesota, (2) northern Minnesota, (3) central and northwestern Minnesota, and (4) southern Minnesota. These areas are delineated in Figure 11. It will be noted that the distribution of nitrogen and phosphorus coincides closely with plant geography of the state (Fig. 16). The least fertile waters are in the coniferous forest area, those of moderate fertility are in the hardwood forest area, and those of high fertility in the prairie region.

TOTAL ALKALINITY—Total alkalinity is a measure of the carbonate content of waters or "temporary hardness" expressed in terms of calcium carbonate. It is a useful chemical measurement but has limitations that should be recognized. First, in waters where the pH exceeds 8.0, monocarbonates are also included in the determination. This causes the results, as calculated in terms of calcium carbonate, to be too low. This error, how-

FIG. 16. Generalized plant geography of Minnesota. FIG. 17. Aquatic floras of Minnesota. Data from Moyle (1945). FIG. 18. Generalized original distribution of fish associations. FIG. 19. Ranges of lake trout and German carp. Solid line is principal range; broken line is limit of range.

ever, in most Minnesota waters is slight. Second, it should be remembered that although total alkalinity is expressed as calcium carbonate, a considerable portion of the carbonates may be and often is associated with metallic ions other than calcium; especially with magnesium. Calcium bicarbonate in pure water is soluble to the amount of 385 ppm at 59°F. (Clarke, 1924, p. 131) while calcium monocarbonate is soluble to the extent of 14 ppm at 77°F. (Hodgman, 1937). Sometimes, however, higher analytical results may be obtained because of suspension of limey material.

Because of the relative insolubility of the monocarbonate, the use of carbon dioxide in the photosynthetic activities of plants often results in the precipitation of calcium carbonate as marl (Thiel, 1933, p. 84). The precipitated monocarbonates will go back into solution again if they come in contact with waters having an excess of carbon dioxide.

Because of the relationship between carbon dioxide and the solubility of calcium carbonates, total alkalinity of waters varies somewhat throughout the year and with the depth of the sample.

In general, the total alkalinity of surface samples from shallow waters tends to be greater than that in surface samples from deep lakes in the same region. Rain-water ponds are an exception. In waters, such as those of Minnesota, where there is a permanent ice cover for several months, total alkalinity is often higher in winter than in summer. In deep lakes where there is a thermocline, total alkalinity is usually greater below than above the thermocline. The difference with depth is likely to be proportionately greater in fertile hard-water lakes than in infertile soft-water lakes. In streams, dilution from rain frequently causes change in total alkalinity.

Such changes and differences in total alkalinity may be illustrated by a few examples. Snail Lake, a hard-water lake with a marly bottom in Ramsey County, ranges in total alkalinity of surface waters from 75 ppm in summer to 150 in winter. In early summer 1949, 17 surface samples from Lake Minnetonka, Hennepin County, had an average total alkalinity of 139.2 ppm and 14 deep-water samples had an average total alkalinity of 162.9. Crystal Lake, a small and probably polluted water in Hennepin County, on September 16, 1948, had a total alkalinity of 120 ppm at the surface and 227.5 below the thermocline. The highest total alkalinity readings in the present series were from shallow waterfowl lakes of western and southwestern Minnesota. Variation in the total alkalinity of rivers can be judged from 24 analyses from the Minnesota River cited by Dole and Wesbrook (1907). These analyses ranged from 105 to 380 ppm around a mean of 220.0.

Total alkalinity expresses concentrations of two substances directly necessary to plant life, calcium and carbon dioxide, and also is a resultant of the entire biological and chemical system of waters. This has lead to the use of total alkalinity as a rough index of the productivity of waters. Within wide limits this is a justifiable approach. Hard-water lakes are usually more productive than soft-water lakes. Total alkalinity can be considered as one of a number of measurements that can be used jointly to evaluate a water. Usually water with a low total alkalinity also has low concentrations of other salts including phosphorus and nitrogenous compounds. Such waters produce scanty plankton crops and often are suited to cold-water fishes because they have ample amounts of oxygen below the thermocline. Aquatic vegetation in lakes of low total alkalinity (below 40 ppm) is usually sparse and is often characterized by such species as *Lobelia Dortmanna*, *Eriocaulon septangulare*, and *Myriophyllum alterniflorum* (Moyle, 1945).

Present evidence suggests that calcium is not a critical factor in the productivity of waters having a total alkalinity greater then 15 ppm (Moyle, 1949), and a good production of fish can be had if other necessary elements are present in sufficient amounts. Gerloff, *et al.*, (1950) found that calcium concentration of 9.8 ppm in their basic culture solution of blue-green algae was excessive, and that optimum growth of *Coccochloris peniocystis* could be had with "only traces of calcium." These same writers found that the concentration of magnesium necessary for optimum growth of this same alga was 0.13 ppm, a concentration lower than that found in even the softer Minnesota waters. Brule Lake, Cook County, for example, in July, 1935, had a total alkalinity of 10.0 ppm, calcium 3.35 ppm, and magnesium 1.09 ppm (analysis by Reif and Smith). Conversely, waters may be fairly high in carbonates but low in some other critical element. Minnesota has several hard-water trout lakes that are apparently trout waters because they are low in nitrogen.

The regional pattern of total alkalinity of standing Minnesota surface waters, as shown in summer samples, is shown in Figure 6.

SULPHATES—Sulphur is an essential component of protoplasm, but it is not known whether this element is a limiting factor in the productivity of Minnesota waters. It should be noted that the lack of sulphates

as shown by analysis in many northern Minnesota waters probably reflects the limitations of the analytical methods rather than a complete absence of such salts. The methods are not reliable for concentrations of sulphate ion below 0.5 ppm.

Gerloff, *et al.*, (1950) found that optimum growth of the blue-green alga *Coccochloris peniocystis*, (*Gloeothece linearis*), was obtained with a concentration of sulphur of 0.083 ppm (0.27 ppm sulphate ion). Miller (1931) in summing up the effect of sulphur on plants noted that plant proteins contain from 0.003 to 7.2 per cent sulphur, and different plants differ considerably in their use of this element.

The general pattern of distribution of sulphates in Minnesota waters is shown in Figure 7. It will be noted that the concentration of sulphates increases from northeast to southwest and is highest where the waters lie in gray drift which in turn is underlain by Cretaceous formations and where evaporation from open water surfaces is greatest. Concentrations of sulphate ion greater than 400 ppm are rare in Minnesota waters, and there is no evidence that the concentrations found in fish lakes are injurious to fish. Pikeperch ponds in the high sulphate area of Minnesota have yielded well.

Rawson and Moore (1944), who investigated relationships between salinity and biological characteristics of 60 lakes in Saskatchewan, found pikeperch and perch in waters with a total salinity of 8,000 ppm. Most of this salinity was of sulphate salts. Many other fish species were found in waters with a salinity greater than 1,000 ppm. They stated . . . "The decrease in the number of species beyond 7,000 p.p.m. suggests that higher salinities are detrimental to most species." In a later paper (Rawson, 1946) recorded successful introduction and growth of whitefish and pikeperch in a lake with a salinity of 15,000 ppm.

There is a noticeable biological relationship between concentrations of sulphates and distribution of aquatic plants in Minnesota. Several species, especially *Najas marina*, *Ruppia occidentalis*, and *Scirpus palustris*, are generally limited to waters with a sulphate ion concentration greater than 50 ppm, and make their best growth in waters where sulphates exceed 200. Some species typical of hard carbonate waters, such as *Potamogeton pectinatus* and *P. Richardsonii*, also grow well in high-sulphate waters, but many of the typical hard-water species do not thrive in them. Wild rice (*Zizania aquatica*) is a plant of this type, and no large stands are known from waters where the sulphate ions exceed 10 ppm. Plantings of wild rice in the high-sulphate water area have generally failed. The cause-and-effect relationship between sulphates and the distribution of plants is not known, but may be related to sulphur demands in plant nutrition, osmotic pressure of the water solution, or the toxicity of magnesium usually associated with sulphates. The general distribution of aquatic floras is shown in Figure 17.

Waters high in sulphates are usually high in carbonates, phosphorus, and nitrogen, but there are exceptions. Fluctuations in sulphates in individual waters appear to be mostly the result of dilution by rain and concentration by evaporation. Higher concentrations of sulphates are known to have occurred in southwestern Minnesota lakes during low water levels of the drought of the 1930's than are now found in the same lakes at high water levels. There is some evidence that in fertile hard-water lakes with a well-developed thermocline, sulphate concentrations may be lower below than above the thermocline. This suggests that under anaerobic conditions below the thermocline sulphates may be reduced to hydrogen sulphide or elemental sulphur. For example, Crystal Lake, Hennepin County, had on September 16, 1948, 14.0 ppm of sulphate ion at the surface, but the sample from below the thermocline had no sulphates and smelled of hydrogen sulphide. Such a sulphur cycle is known from marine waters (Sverdrup, *et al.*, 1942, p. 916). Buchanan and Fulmer (1928, pp. 417–420, 434) noted that "hydrogen sulphide—is developed under anaerobic conditions by various micro-organisms from sulphates and from organic compounds." A recent summary of the sulphur cycle in streams and lakes by Fjerdingstad (1950) agrees with the foregoing conclusions and shows that hydrogen sulphide has a marked effect on the plankton fauna and flora.

CHLORIDES—The concentration of chloride ion in Minnesota waters, as found in this series of analyses, ranges from zero to 113.0 ppm. Except for a single analysis, all are

"infrahalinous" or non-brackish waters according to the chloride classification of waters by Olsen (1950). Most Minnesota waters have a chloride content below 5 ppm and only in the southwest are higher concentrations common. Usually high concentrations of sulphates and chlorides occur together. As with sulphates, high concentrations of nitrogen and phosphorus are often associated with high chloride concentrations. The general distribution of chloride concentrations in the state is shown in Figure 8.

It is not known whether the concentrations of chlorides in Minnesota waters have any direct effect on the biology of the waters. The literature of plant physiology (Miller, 1931) shows considerable difference of opinion as to the value of this element in plant nutrition. It has long been known that high concentrations of chlorides are related to plant distribution. This may well be an osmotic effect for it has been demonstrated there are optimum osmotic concentrations for plants. As noted by Gerloff, *et al.* (1950) . . . "both the extent of uptake and actual requirements for each ion will be determined in part by concentrations of other ions in the nutrient solution."

High concentrations of chlorides in areas where chlorides are normally low may indicate pollution. For example, Lake Henry, in Douglas County, which receives effluent from the sewage treatment plant of the city of Alexandria, had 88.5 ppm chlorides, a concentration several times greater than non-polluted lakes in the same area. Purified effluent liquids from sewage treatment plants tend to be high in chlorides; that from the city of Detroit Lakes analyzed 50 ppm in the summer of 1948. Ponds in which cattle stand are often high in chlorides and a similar condition is found in lakes of metropolitan areas where water is received from icy streets and sidewalks that have been salted during the winter.

PHOSPHORUS—Phosphorus in surface waters occurs both as phosphate phosphorus and as organic phosphorus (phosphorus tied up in living matter and other organic material). As considered here, total phosphorus represents all phosphorus obtained by acid digestion from a non-filtered sample.

On many of the samples, both total phosphorus and phosphate phosphorus were determined. The ratio between total phosphorus and phosphate phosphorus is variable and fluctuates throughout the year and even during short periods of time. In ponds, phosphate phosphorus tends to be high in the spring and low in midsummer when a plankton bloom has developed. In midsummer, in lakes and ponds, phosphate phosphorus usually makes up less than a third of the total and may at times be lacking.

The solubility of phosphates in water is related to the pH. As shown by the experimental work of Drake and Owen, (1950), phosphates are nearly insoluble at a pH of 10.5. These workers are of the opinion that at a high pH phosphorus tends to be precipitated in the presence of calcium carbonates as calcium (ortho)phosphate. It is likely that a rise in pH caused by photosynthesis in natural waters may result in some precipitation of phosphates along with the monocarbonates, and that these precipitated phosphates go into solution again when an excess of carbon dioxide becomes present. A formula for this reaction was proposed by Troug (1916):

$$Ca_3(PO_4)_2 + 2H_2CO_3 \rightleftarrows Ca_2H_2(PO_4)_2 + Ca(HCO_3)_2$$

McGeorge and Breazale (1931) postulated that phosphates are precipitated from soil waters as a complex calcium-phosphate-carbonate which again becomes soluble in the presence of carbon dioxide.

In the samples of surface waters taken from lakes and ponds, the total phosphorus content ranged from 0.002 to 1.6 ppm. The regional distribution of these concentrations is shown in Figure 9. As with the other chemical components of the waters, there is a general increase from northeast to southwest, and on the average, the phosphorus content of the southwestern waters is about seven times that of the extreme northeast. There is also a general relationship between the total concentration of salts and the phosphorus content, but there are many exceptions. Usually ponds and waterfowl lakes have higher concentrations of phosphorus than the deeper fish lakes in the same area. This relationship is probably the result of greater area of bottom in proportion to volume in the shallower waters and the lack of thermal stratification. In stratified fish lakes, especially hard-water lakes of high fertility, there is considerable accumulation of phosphorus below the thermocline. Thus,

in Lake Minnetonka, Hennepin County, in early June, 1949, at a time when the thermocline was not yet fully developed, the mean total phosphorus content of 17 surface samples was 0.05 ppm, and the mean of 13 deep water samples was 0.20. Even greater contrast can be expected at the end of the summer. On September 16, 1948, Lake Crystal, Hennepin County, had 0.10 ppm of phosphorus at the surface and 1.4 below the thermocline. Difference in phosphorus concentration with depth is less marked in waters of lower fertility in northern Minnesota. In Lake Superior off Beaver Bay, Minnesota, the total phosphorus content of the water was found to be similar from top to bottom and ranged from 0.015 to 0.02 ppm.

A number of Minnesota lakes have objectionable blue-green algal blooms in midsummer. These are mostly lakes that lie in fertile areas and which are not deep enough to develop a well-defined thermocline. It is likely that the circulation of inorganic phosphorus in such lakes is a major cause of the bloom since it allows a continuous supply of phosphate phosphorus for the algal crop. The average total phosphorus content of 38 unfiltered samples with noticeable blooms was 0.191 ppm. The total phosphorus content of this series ranged from 0.03 to 1.0 ppm. Gerloff, *et al.*, (1950) found in culture that the minimum concentration of inorganic phosphorus associated with optimum growth of the blue-green algae (*Coccochloris peniocystis*) was 0.45 ppm.

In a later paper (Gerloff and Skoog, 1954) it is noted that *Microcystis*, when grown in culture media rich in phosphorus and nitrogen, accumulates these substances in the cells. These authors suggest that the algal cells . . . "might absorb sufficient quantities of various elements to permit considerable growth after being carried into nutrient-deficient surface layers." Occurrence of such stored excess phosphorus in the algae would, of course, increase the amount found in nonfiltered samples taken from the surface of a lake with a bloom.

Knowledge of phosphorus (as phosphate) in the ground water of the glacial drift of Minnesota is limited to the studies of Allison (1932) in the northwestern counties. A recalculation of his data for Area 7 in Figure 5 is presented below along with data for total phosphorus from the present series of surface waters from this same area:

> mean of 29 samples from glacial soil, 2.9; mean of 70 samples from ponds, 0.157; mean of 40 samples from waterfowl lakes, 0.086; and mean of 55 samples from fish lakes, 0.04 ppm.

In any lake or pond the phosphorus content of surface waters can be expected to vary within a certain range even during the summer season. This natural variation combined with sampling and analytical errors makes evaluation of waters on the basis of a single analysis uncertain. The expected extent of the variation can be judged from a series of weekly analyses made on three unfertilized ponds near the Twin Cities in the summer of 1941 (Smith and Moyle, 1945):

Pond	Total Phosphorus, ppm	
	Mean	Range
South Palm	0.058	0.04 –0.08
St. Paul No. 3	0.062	0.05 –0.10
St. Paul No. 4	0.058	0.045–0.06

A single phosphorus analysis from a water should be regarded only as an indication of fertility to be used in conjunction with other data in evaluating a water.

NITROGEN—Combined nitrogen in surface waters occurs in four forms: (1) ammonia nitrogen, (2) nitrate nitrogen, (3) nitrite nitrogen, and (4) organic nitrogen (nitrogen of protoplasm, amino acids, and other organic compounds dissolved or suspended in water).

The total nitrogen content of the present series of surface water analyses ranged from 0.06 to 5.92 ppm. The general distribution pattern of nitrogen concentrations, as shown in Figure 10 is similar to that described for phosphorus. There is a general increase from northeast to southwest across the state. On the average, waters of the southwest (Area 9, Fig. 5) have 5.2 times more nitrogen than those of the extreme northeast (Area 1, Fig. 5), and the intervening areas have intermediate values.

Occasionally, nitrogen appears to be a limiting factor in the productivity of Minnesota waters. There are several hard-water trout lakes in Itasca County that have moderate concentrations of salts including phosphorus but seem to retain their oligotrophic character because of low concentra-

tions of nitrogen. The mean total nitrogen of three such waters, Bluewater, Big Trout, and Little Trout, was 0.174 ppm and mean total phosphorus 0.033 ppm. The phosphorus content of these lakes is about normal for fish lakes of the region but the nitrogen concentration is about half what might be expected.

The proportions of the several nitrogenous compounds found in Minnesota surface waters vary considerably and are probably related to the status of plant plankton pulses, the amount of bacterial nitrogen fixation going on, and the amount of decay of organic material which is releasing ammonia into the water. Nitrites are frequently absent in freshly collected surface samples from lakes, and when found are usually in concentrations below 0.05 ppm. In summer, nitrates are usually not found in concentrations greater than 0.1 ppm in surface waters of lakes. High concentrations (above 1.0 ppm) are common only in streams in the vicinity of springs. Ammonia nitrogen concentration in summer surface waters is usually below 0.2 ppm except in polluted waters and in very fertile ponds or lakes in which there is considerable decay going on. The following mean proportion of nitrogenous compounds expressed as N found in 17 freshly collected surface samples from Lake Minnetonka, Hennepin County, in June, 1948, can be regarded as fairly typical of Minnesota hard-water lakes in early summer:

	Nitrite	Nitrate	Ammonia	Organic
Mean, ppm	0.009	0.056	0.110	0.438
Percentage of total	1.5	9.1	17.9	71.4

As with phosphorus, nitrogen tends to accumulate below the thermocline in summer. The proportionate difference between surface and deep-water analyses tends to increase with the total fertility of the water. It is most marked in polluted waters and least marked in oligotrophic lakes. As an example of nitrogen accumulation in the deep waters, means of 14 deep-water samples taken from Lake Minnetonka the same time as the preceding series are cited:

	Nitrite	Nitrate	Ammonia	Organic
Mean, ppm	0.012	0.10	1.55	0.18
Percentage of total	0.6	5.4	84.2	9.8

The deep waters of Lake Minnetonka had about three times the nitrogen content of the surface waters, 1.84 as contrasted to 0.61 ppm, and whereas 71 per cent of the nitrogen at the surface was in the organic form, most of the nitrogen in the deep water was in the form of ammonia.

Crystal Lake, Hennepin County, a water of high fertility had the following analysis of nitrogen in parts per million at the end of the summer stratification period (September 16, 1948):

	Nitrite	Nitrate	Ammonia	Organic	Total
Surface	0.008	0.10	0.05	0.308	0.476
Below thermocline	0.004	0.20	8.00	0.00	8.20

In contrast, Lake Superior, which is at the other end of the fertility series, showed little variation from top to bottom in a series of samples taken off Beaver Bay, July 14–17, 1949. The analyses are:

Depth — feet	Total nitrogen, ppm
Surface	0.088
340 feet	0.12
820 feet	0.10

Nitrogen content of waters in ponds and shallow lakes often is high in early spring because of the accumulation of nitrogenous compounds that have been released by decay of organic material under the ice. Compare, for example, the following analysis from a sample taken from beneath the ice on Crystal Lake, Hennepin County, in February with the analysis already cited for this lake.

	Nitrite	Nitrate	Ammonia	Organic	Total
Beneath ice	0.025	0.39	1.05	0.95	2.42

Total nitrogen beneath the ice was about four times greater than that found in the surface water in the fall.

It should be pointed out that ammonia in high concentration is toxic to fish. Ellis, Westfall, and Ellis (1946) note that . . . "ammonium compounds are generally detrimental or lethal if more than 2.5 p.p.m., of ammonia are represented."

Little is known about the role of ammonia in the nutrition of plant plankton of fresh waters. Marine workers consider nitrates to be the principal source of nitrogen for ocean plankton but it has been shown that ammonia is used by unicellular algae (Sverdrup, *et al.*, 1942, p. 914). Miller (1931, pp. 501–503) notes that some higher plants can

utilize ammonia and some cannot but that, in general, plants seem to prefer nitrates to ammonia as a source of nitrogen.

High concentrations of nitrites may also indicate pollution. Nitrites also tend to increase in water samples that have been held too long before analysis.

The relationship of nitrogen to fertility and biological use of waters follows a pattern similar to that already discussed for phosphorus.

PHOSPHORUS-NITROGEN RATIOS—Both phosphorus and nitrogen are essential elements in protoplasm and either may at times be present in such low concentration that it limits the productivity of a water. Fertilization of waters is based on experiences of fish culturists who have found that the addition of phosphorus and nitrogen, either in the inorganic or organic form, often increases yields. The most usual ratio between these two elements is, therefore, of considerable interest and appears to be about 1 : 7 in living matter. However, there is considerable variation shown for different kinds of plants and animals. The following ratios are typical:

Organism	P : N	
Indian corn	1 : 7.2	(Miller, 1931, p. 233)
Cabbage	1 : 8.0	(ibid., p. 234)
Wheat	1 : 7.0	(ibid.)
Marine zooplankton	1 : 7.4	(Fleming, 1940)
Marine phytoplankton	1 : 7.0	(ibid.)
Marine diatoms	1 : 6.7	(Sverdrup, et al., 1942, p. 234)
Calanus (marine copepod)	1 : 11.6	(ibid., p. 233)
Microcystis (bluegreen alga)	1 : 9.9	(Gerloff and Skoog, 1954)

Sverdrup, *et al.*, (1942) use the ratio 1 : 7.2 in their considerations of plankton production in the sea and cite the following theoretical relationship between amounts of oxygen, carbon, nitrogen, and phosphorus utilized by plant plankton:

$$O : C : N : P = 109 : 41 : 7.2 : 1$$

The ratio of 1 : 7.2 in marine plankton is close to that found between phosphate phosphorus and nitrate nitrogen in ocean water; 1 : 6.8 (recalculated from Sverdrup, *et al.*, 1942, p. 243). In the present series of analyses the average ratio between phosphate phosphorus and nitrate nitrogen in 258 surface-water samples from fish lakes was 1 : 7.5.

However if the total phosphorus and total nitrogen in the biological-chemical system of Minnesota surface waters are considered, a greater proportion of nitrogen is found. In an earlier paper (Moyle, 1949) a total phosphorus to total nitrogen ratio for surface waters of lakes and ponds of 1 : 11.1 was reported. The present series of analyses suggests a most usual ratio of about 1 : 10. Some of the excess nitrogen is in the form of ammonia and a very small amount as nitrites, but it appears that much of this excess nitrogen must be incorporated in dissolved and suspended organic matter.

IRON—During the course of the chemical investigation, total iron was determined on 55 surface samples. These analyses are too few and too irregularly distributed to allow any detailed discussion. They range from zero to 6.0 iron with a mean of 0.34 ppm and a median of 0.08. The only large series from fish lakes is that of 24 analyses from Crow Wing and Aitkin counties. Here the range is zero to 0.124 ppm with a mean of 0.051 and a median of 0.045.

Gerloff, *et al.*, (1950) note that maximum growth of the blue-green algae (*Coccochloris peniocystis*) at iron concentrations of 0.03 ppm.

NATURE OF THE RELATIONSHIP BETWEEN WATER CHEMISTRY AND FISH PRODUCTION

Many indices of the productivity of fresh waters have been proposed, and for a discussion of them the reader is referred to Welch (1935, pp. 321–325) and Moyle (1949). They include biological indices, such as plankton, bottom fauna, and aquatic plant production, and such chemical indices as total alkalinity, phosphorus, nitrogen, and total dissolved solids. The size and shape of a lake basin are pertinent to its productivity. Rounsefell (1946) shows that a general relationship can be demonstrated between the surface area and size of fish crops. Rawson (1952) relates fish yield to mean depth of large lakes. All of these methods have merit since they are reflections of the entire microcosmic system of waters. However, the application of such indices to specific waters is difficult and often uncertain.

It is interesting, through use of the present series of analyses, to attempt to sketch the general nature of the relationship between water chemistry and the size of the fish crop of waters. Four such general relationships are shown graphically in Figures

12 through 15. These graphs were drawn by plotting the mean concentrations of chemical components of waters in the areas of similar fertility shown in Figure 5 against rough estimates of the size in pounds per acre of available water of representative and typical fish populations. The fish-population data are drawn from seining, interpretation of gill-net catches, and commercial fishing. Some of the basic data are from Moyle, Kuehn, and Burrows (1950).

On a regional and average basis, there is an apparent relationship between the summer phosphorus content of surface waters and both the size and structure of fish populations. In the northeast, the waters having a total phosphorus content of 0.02 ppm or lower usually have oxygen below the thermocline and are often suited to lake trout (*Cristovomer namaycush*) and associated species, especially tullibee (*Leucicthys artedi*) and white suckers (*Catostomus c. commersoni*). Centrarchids are usually absent. The average weight of the fish population in such waters is estimated from netting, commercial fishing, and angling to be about 40 pounds per acre.

Northeastern Minnesota (Area 2, Fig. 5) is the principal natural range of the yellow pikeperch or walleye (*Stizostedion v. vitreum*). With the walleye are commonly associated yellow perch (*Perca flavescens*), northern pike (*Esox lucius*), brown and yellow bullheads (*Amieurus* spp.), and white suckers (*Catostomus c. commersoni*). Centrarchids, especially largemouth bass (*Micropterus salmoides*), bluegills (*Lepomis macrochirus*), and black crappies (*Pomoxis nigro-maculatus*) occur, and are sometimes abundant in smaller lakes, but often have a slower growth rate, as shown by scale analysis, than in more fertile waters. It has been estimated on the basis of surveys, that the Mississippi headwater lakes, which are typical of this area, carry about 90 pounds of fish per acre. Such lakes have mean total phosphorus content of summer surface waters of fish lakes of about 0.034 ppm.

In central Minnesota (Areas 3, 5, and 7, Fig. 5), the lakes were originally mostly bass-panfish waters, and despite 50 years of pikeperch stocking, the panfishes still supply the bulk of the fishing. The mean total phosphorus content of the present series of fish lakes in these areas is 0.058 ppm. The best present estimate for average fish carrying capacity of better waters of this area is about 150 pounds per acre, if fish of all kinds and sizes are included.

In southern Minnesota (Areas 6 and 9, Fig. 5), most lakes have populations of rough fish, especially carp (*Cyprinus carpio*), buffalofish (*Megastomatobus cyprinella*), black bullhead (*Ameiurus melas*), and sheepshead (*Aplodinotus grunniens*). Centrarchids are also present, and many of these lakes have been stocked with pikeperch and white bass (*Lepibema chrysops*). These waters have been subjected to intensive rough-fish-removal operations for 25 years. Seining in 40 such waters showed an average standing crop of 280 pounds of rough fish per acre plus about 90 pounds of other fishes, a total of 370 pounds per acre (Moyle *et al.* 1950). The mean total phosphorus content of surface waters of fish lakes in this region for the present series of analyses was 0.126 ppm.

When figures for the size of typical fish populations and the mean total phosphorus of surface waters associated with them are plotted against each other the relationship approximates a straight line (Fig. 12). The relationship is probably partly one of cause and effect and partly the result of similar factors influencing both the size of the fish population and the concentration of phosphorus in the water. This relationship suggests that (1) the size of population of mixed fish is related to the water fertility and conditions associated with it and (2) that the structure of a fish population adjusts itself until it is made up of those species that can best utilize a specific degree of fertility and conditions associated with it. That is, a natural balance tends to be achieved between the size and structure of the fish population and the chemistry of the water and the factors which influence that chemistry. Fish-management procedures should be considered in this light for often "corrective stocking" and "rough-fish removal" are aimed at changing the structure of fish populations that are already in natural balance with the physical and chemical environment.

Although the relationship of the carrying capacity of water to phosphorus fertility appears to approach a straight line, it is likely that the relationship of the size of the population of any particular species to water fertility is a curve. Each species of

fish has certain optimum conditions under which it thrives best and is most abundant. Thus, in Minnesota, the optimum phosphorus content associated with lake trout appears to be around 0.02 ppm, with pikeperch around 0.035, with centrarchids around 0.05, and with carp around 0.1. In waters of either higher or lower fertility than the optimum, any particular species is likely to be less successful both because of change in the environment and food production associated with change for fertility, and because of competition with other species for whom the environment is nearer the optimum.

It has been frequently demonstrated in ponds that fertilization of waters will increase the yield of fishes of many species grown either singly or in certain select combinations, such as bluegills and black bass. However, such an increase in fish yield can be obtained only to a certain optimum point above which the yield curve flattens out and finally declines rapidly as conditions become unfavorable to that species. For example, in a study of yield of Minnesota pikeperch ponds (Smith and Moyle, 1945), maximum yield was from ponds within the total phosphorus range of 0.05 to 0.1 ppm, and waters of higher fertility did not produce higher yields of fish. It is likely that the flattened "asymptotic" portion of the curves is at different levels for different species, and that a pond-fertilization scheme which will obtain optimum production for a single species or group of species is not the same as the level providing optimum conditions for another species or group of species.

A large part of the phosphorus determined as total phosphorus in summer surface waters is organic phosphorus, that is, phosphorus in plankton and organic detritus. The relationship shown, therefore, is similar to that demonstrated by Swingle and Smith (1939) between plankton production and fish production in ponds. It should be noted that although total phosphorus is a direct expression of the amount of phosphorus in and available to the plankton cycle, it is also an indirect and resultant expression of the physical, chemical, climatic, biological, and edaphic factors which influence the growth of plankton crops.

A similar relationship can be demonstrated for total nitrogen and fish population (Fig. 13). A relationship between organic nitrogen in the water and yield of bass ponds in West Virginia has been pointed out by Surber (1947). However, he found no relationship between yield and the concentrations or inorganic nitrogenous compounds.

Total alkalinity when plotted against size of representative fish populations forms a parabolic curve which rises rapidly for high concentrations. Probably the relationship shown is the result of increasing concentrations of less abundant substances such as nitrogen and phosphorus associated with higher carbonate concentrations rather than any effect of the carbonates themselves (Fig. 14).

Total dissolved solids, that is the weight of all dissolved and suspended matter in a filtered sample, was considered as a measure of basic fertility by Eddy and Carlander (1940). Rawson (1951) noted differences in productivity between Great Bear and Great Slave Lakes which were associated with the marked differences in the total-solids content of these waters.

Total dissolved solids were not determined on the present series of samples, but approximate salinity has been calculated which give values of the same general magnitude. A sum was obtained of all carbonates as calcium carbonates, all sulphates as magnesium sulphate, and all chlorides as sodium chloride. The calculated salinity is plotted against size of typical fish populations in Figure 15. The relationship within the range of salinity of Minnesota waters is a parabolic curve, similar but flatter than that for total alkalinity. This curve, like that for total alkalinity, probably reflects the tendency of lesser elements necessary for growth to increase as salinity increases.

It should be emphasized that there are many uncertainties in the considerations just discussed and that the apparent relationships are complex and are probably both coincident and to a certain extent cause and effect.

WATER CHEMISTRY AND BIOLOGICAL PATTERNS—Four general biological patterns for the state of Minnesota are shown in Figures 16–19. It will be noted that these biological patterns show the same type of alinement that has already been noted for the chemistry of surface waters where the lines run across the state in a general northwest-

southeast direction. The similarity of patterns reflects the effect of climate and soil upon the chemistry of the surface waters, the plants and animals which inhabit these waters, and the surrounding land.

If Figure 16, which shows the major plant formations of the state, is compared with the foregoing figures on water chemistry it will be noted that the line which separates coniferous from hardwood forest roughly coincides with the following chemical isolines: chloride ion, 1.0 ppm; sulphate ion 2.0 ppm; total phosphorus, about 0.04 ppm; and total nitrogen, about 0.4 ppm. In general, waters of the coniferous forest region are also likely to have a lower carbonate hardness (total alkalinity) than those of the hardwood region.

Similarly, the line separating hardwood forest from prairie coincides roughly with the following chemical isolines: chloride ion, about 5 ppm; sulphate ion, about 10.0 ppm; total phosphorus, about 0.1 ppm; and total nitrogen, about 1.0 ppm. Usually the prairie lakes are higher in salts of all kinds including compounds of phosphorus and nitrogen than those of the coniferous or hardwood forests.

The general distribution of types of aquatic vegetation is shown in Figure 17. The distribution of typical soft-water species, such as *Lobelia Dortmanna* and *Isoetes Braunii* is fairly well delimited by the total alkalinity isoline of 40 ppm. These waters are also low in other salts and in chemical nutrients. The typical hard-water flora is best developed between total alkalinity isolines of 40 and 200 ppm and in waters where the sulphate ion concentration is less than 10 ppm; the chloride ion concentration is less than 2 ppm; and the total phosphorus less than 0.5 ppm. The alkali-water flora, characterized by *Ruppia occidentalis* and *Najas marina*, is usually found in waters with a total alkalinity greater than 200 ppm, and sulphate ion concentration greater than 50 ppm. Concentrations of other salts in these waters are also high.

Areas typified by different fish associations are shown in Figure 18. It will be seen that the trout-tullibee waters are those low in salts of all kinds. The pikeperch waters range in total salt concentrations from low to high (with most of the salts being carbonates) but are generally included with the following chemical isolines: total phosphorus, 0.04 ppm; total nitrogen, 0.4 ppm; chloride ion, 1.0 ppm; and sulphate ion, 2.0 ppm. Both the trout-tullibee and pikeperch-perch-pike associations are typically associated in Minnesota with coniferous forest. It might also be noted that within its typical range the pikeperch usually produces a sizeable year class each year in suitable lakes. In more fertile waters, such as those of southern Minnesota the reproduction of introduced pikeperch populations is sporadic and often lacking and year classes are mostly associated with previous fingerling stocking. In lakes of low fertility in the northeast, introduced pikeperch have in a number of cases displaced lake trout but growth of the pikeperch is usually slower than in their typical range.

Black bass-sunfish-crappie-pike waters are typically more fertile than pikeperch waters and are usually associated with the hardwood forest. They have the chemical characteristics already described for the hardwood forest. Similarly rough-fish waters have the still higher fertility already described for the prairie region.

The distribution of two fish species that are associated with opposite ends of the range of chemical fertility found in Minnesota lakes are shown in Figure 19. The lake trout (*Cristivomer namaycush*) is now found only in the soft and infertile waters of the northeast. Its original range is now somewhat contracted because of the introduction of pikeperch into trout waters. It will be seen that the original range coincided roughly with the total alkalinity isoline of about 40 ppm, or the range of the soft-water flora. This probably marked the boundary of those waters which had ample oxygen below the thermocline in midsummer. At the other end of the chemical range is the carp (*Cyprinus carpio*). This fish has been in the state since 1882 and has been able to migrate through many streams. Despite this it has not migrated much beyond the total phosphorus isoline of 0.05 ppm, and its greatest abundance is in more fertile waters.

It should be noted that air and water temperatures also increase from northeast to southwest during the summer. This temperature gradient also has an important effect on the distribution of fish. Trout are cold-water species, bass and other centrarchids are tolerant of quite warm waters, and pikeperch are apparently intermediate.

The foregoing relationships are expressed on a general geographical basis and admit many exceptions. They should be considered as a contribution to the knowledge of the general ecology of Minnesota rather than a specific basis for the interpretation of individual aquatic problems.

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OBITUARIES

GARDINER F. JONES

1913 – 1955

Gardiner F. Jones, research project leader for the Washington Game Department, died October 20 in Aberdeen, Washington. His passing culminated a valiant but futile six-month battle with cancer.

Gardiner was born at Harrington, in eastern Washington, but most of his youth was spent in California. He attended the University of California for two years prior to accepting employment with the California Division of Fish and Game in 1937. After seven years of patrol and predator control work for the division he left to complete his college training at Washington State College. There he received his B.S. degree in wildlife management in 1948.

After a short term as beaver trapper for the Washington State Department of Game he was promoted to leader of the Black-tailed Deer Research Project when it was initiated in 1949. It was here that Gard displayed his leadership talent and his keen mind in making the project an outstanding contribution to wildlife research. He was not content to merely search out truth, but he voluntarily attacked the problem of public education to put research findings into practice. Gardiner and his crew worked tirelessly conducting research activities during the day and attending meetings with illustrated lectures on game management at night. The research project had an important part in securing either-sex seasons for harvesting deer in much of the state.

Gardiner's entire life was dedicated to serving the science of wildlife conservation and research. He worked faithfully and tirelessly because he loved the work. His fine character was evident by the esteem in which he was held by his many friends and associates.

In addition to his membership in the Wildlife Society, he also belonged to the Society of Range Management and the Pacific Northwest Bird and Mammal Society of which he was president at the time of his death.

Gard's passing is a serious loss to the Washington Game Department and to the entire field of wildlife conservation and management.—J. BURTON LAUCKHART.

CHARLES H. HOPKINS

1893 – 1956

Mr. Charles H. Hopkins was born in Wyandotte County, Kansas, on September 21, 1893, and died on March 22 in St. Anthony's Hospital, Alton, Illinois, where he had been a patient since suffering a heart attack on February 12.

Mr. Hopkins was graduated from Nazareth (now St. Joseph's) College at Muskogee, Oklahoma, in 1909, where he received technical training as a petroleum engineer. Early in his career he entered newspaper work and served as a reporter and city editor for several newspapers in the Southwest. He served in the Navy during World War I and in the U. S. Army and Oklahoma National Guard from 1924–1939, leaving the service with the rank of captain. In 1934, he was appointed advertising manager of Olin Industries, Incorporated and advanced to manager of advertising and promotion, director of shooting promotion, and director of the company's conservation activities. In 1953, he was appointed director of the Olin Mathieson Chemical Corporation's newly formed conservation department and devoted his full time and energy to this task to the time of his fatal illness. Part of his duties consisted of administering Nilo Farms, a highly successful and much publicized project designed to demonstrate practical methods of operating private shooting preserves.

Although he never received formal training in

wildlife management or biology, he was an avid reader of the technical journals in these fields and through rigorous self education became exceptionally well informed in technical phases of game management. An early advocate of wildlife habitat restoration, he inaugurated the Winchester-Western Game Restoration Plan in 1935. This plan had the objective of increasing wildlife production on private lands through the planting and development of essential food and cover. The program later was coordinated with the modern farm planning practices of the Soil Conservation Service and was a forerunner of similar plans conducted by the states in more recent years.

Mr. Hopkins was a firm believer in practical research and devoted much of his time and energy toward furthering the quality and quantity of wildlife research and investigation. With his staunch support, large sums of private money were channeled into agencies, organizations, and institutions to finance fish and game studies, and the promoting of better management of natural resources in the public interest. He worked tirelessly in building public support for the enactment of the Pittman-Robertson and Dingell-Johnson Federal Aid in Wildlife and Fisheries Acts.

Mr. Hopkins was an expert shot with rifle, shotgun, and pistol. He was a member of the Winchester-Western Champions Club, whose members are title holders in national, regional or state trap or skeet shooting tournaments, and a life member of the National Rifle Association of America.

In his official capacity, he supervised the preparation of numerous technical publications on firearms and was the author of the "Handbook of Shotgun Shooting," which is published and distributed by the Sporting Arms and Ammunition Manufacturers' Institute. Mr. Hopkins also helped to perfect many technical advances in the development of popular sporting ammunition. An avowed foe of anti-firearms legislation, he fought hard over the years against fallacious crime prevention bills that would disarm the citizens to the advantage of the criminals.

"Cap" Hopkins' interest in the out-of-doors began when he was a boy in Indian Territory. It developed into a keen and enduring passion that sustained him through periods of physical and mental strain that would have bed-ridden a man of lesser courage and stamina. In 1939, he was in an automobile accident that shattered his right kneecap. Later, and before he really should have been out of the hospital, while speaking at a conservation club banquet in St. Louis, he slipped and fell on the injured leg. A long series of complicated and painful operations failed to restore more than partial use of the seriously damaged limb. Despite the need for daily medications, he participated in field activities and attended numerous conservation gatherings, including all recent North American Wildlife Conferences. He fished and hunted at every opportunity, often on crutches or with a cane, and even during his many periods of confinement carried on his work and studies from his hospital bed.

He was instrumental in the establishing of the Rudolf Bennitt Memorial Forest and Wildlife Area near Ashland, Missouri, and the erecting of a bronze memorial along the Current River to another of the pioneer conservationists, Senator Harry B. Hawes. In 1951, Hopkins himself received the first merit award ever presented by the Advisory Board of the Illinois Conservation Department for distinguished service to the cause of conservation.

Characteristic of the indomitable spirit of the man, "Cap" Hopkins on his death-bed, refused to relinquish plans to attend the Twenty-first North American Wildlife Conference even though his doctors informed him that attendance was impossible. At his insistence a hotel room was held for him throughout the Conference. Only the firmest restraint by his medical attendants prevented him from carrying out his resolution.

Two weeks after the close of the Conference, he died. The conservation movement lost a loyal friend whose determination, devotion, and contribution to the cause can be known and appreciated fully only by those close friends who watched him fight for conservation, as he preferred, anonymously and behind the scenes.—C. R. GUTERMUTH.

JAMES W. WHEELER

1923 – 1955

James Willard Wheeler, District Game Supervisor of the Michigan Department of Conservation, stationed at the Pte. Mouillee State Game Area, was electrocuted at his home the night of August 9, 1955. He was in the crawl-space beneath the state-owned residence exploring for a television connection when he touched a furnace duct that was in contact with an electric wire.

Jim Wheeler, born February 20, 1923, at Mt. Pleasant, Michigan, almost literally inherited a career in conservation. His father is George R. Wheeler, professor of agriculture at Central Michigan College and a life-long worker for the conservation of fundamental resources. Jim's natural bent for hunting, fishing, and outdoor living led him toward wildlife management.

His undergraduate work at Central Michigan College was interrupted by World War II. As a marine corps fighter pilot he served at Okinawa and later in Japan. He received his B.S. degree from Central in 1947 and entered the University of Michigan for further study. From Michigan he received degrees of B.S. in Forestry and Master of Forestry (wildlife series). At the University he

used his flying experience in an effort to work out aerial methods of censusing deer.

After completion of his graduate studies, Wheeler joined the Game Division of the Michigan Department of Conservation in July, 1949. His work for the Department was varied, including a half year as farm planner on the wildlife habitat improvement project, a year and a half as district game supervisor at Gladwin, and a total of four years at the Rose Lake Wildlife Experiment Station, East Lansing. At Rose Lake he was in turn farm superintendent, research biologist, and assistant in charge of research.

His tragic death occurred less than two months after his transfer from Rose Lake to the Pointe Mouillee assignment, which included most of the Detroit area. Because of his enthusiasm, warm personality, and wide experience Wheeler was considered an ideal choice for his new position, with its extra heavy load of public relations in addition to a district game supervisor's other duties.

Jeanne Wheeler, Jim's wife, is now working as a secretary at the Rose Lake Wildlife Experiment Station, Route 1, East Lansing. With her are their two sons, aged 5 and 1.—H. D. RUHL.

ASA ORRIN WEESE

1885 – 1955

Asa Orrin Weese, distinguished ecologist and teacher, and a charter member of the Wildlife Society, died in Norman, Oklahoma, on November 20, 1955.

Dr. Weese was born in Hutchinson, Minnesota, on November 7, 1885. He received his bachelor's degree from the University of Minnesota in 1909. He attended summer sessions at the University of Minnesota in 1909 and 1910, the University of California in 1913, and the University of Chicago in 1914. He followed V. E. Shelford to the University of Illinois in the summer of 1915, receiving his master's degree from that institution in 1917 and his Ph.D. in 1922. Meanwhile, in 1911, he had become assistant professor of biology at the University of New Mexico. In 1914 he was made a full professor. On June 2, 1915, he married Josephine Moseley of Litchfield, Minnesota. In 1918 he became professor of animal biology and botany, director of the Department of Hygiene (Health Service), and acting dean at the University of New Mexico. From 1922 to 1924 he taught biology at James Millikin University. In the summer of 1924 he and his wife took a trip to Alaska.

In the fall of 1924 he joined the faculty of the University of Oklahoma. Here, in addition to his teaching duties, he served as ecologist for the Oklahoma Biological Survey, as editor of all Survey publications, and as research associate in the zoology division of the University Museum. He taught the first courses in quantitative biology and bioecology ever offered at the University. In 1946–1947 he was acting dean of the Graduate College. From 1948 on, he held a David Ross Boyd professorship.

He devoted much time to research and fieldwork. He assisted in presenting a course in marine ecology at the Puget Sound Biological Station, Friday Harbor, Washington, in the summer of 1924, giving the course himself in the summers of 1925 and 1929. From 1928 on he spent most of his summers teaching ecology at the Rocky Mountain Biological Laboratory, at Gothic, Colorado. In 1938 he became president of the Laboratory's board of trustees, a position he held the rest of his life. He was much interested in the behavior responses of animals to environmental conditions, in the organization of animal and plant communities, and in succession. He experimented with several marine and prairie-inhabiting animals, notably jellyfishes and horned lizards. He made detailed studies of certain bottom communities in Puget Sound, and of the invertebrates of a tract of oak-maple forestland in Illinois.

Soon after moving to Oklahoma he became a member of the Oklahoma Academy of Science. He was that organization's president from 1931 to 1933, its permanent secretary from 1946 on. In 1954 he was elected a life member. He was president of the Grasslands Research Foundation; secretary-treasurer, then president, of the Ecological Society of America; and president of the Ecologists' Union. From 1933 on he was a member of the National Research Council's Committee on Ecology of Grasslands. He collaborated with Encyclopedia Brittanica Films, Inc., in producing the educational film, "Life in the Grasslands." For a time he was chairman of the Ecological Society's Committee on the Preservation of Natural Conditions for the United States. He was especially interested in the Wichita National Wildlife Refuge in Oklahoma. Among the other professional organizations to which he belonged were the British Ecological Society, The Nature Conservancy, American Society of Zoologists, American Association for the Advancement of Science, Sigma Xi, Phi Kappa Phi, and Phi Sigma.

As a teacher and member of the University's Department of Zoology he was much loved and respected. His fellow faculty members continued to be amazed at his fund of knowledge concerning ecological and biological matters. Even during the last year of his life, when he was sorely handicapped by heart trouble, his figure was a familiar one on the campus. Early on Saturday mornings his face often wore a broad smile. With station wagon filled with gear, and his students, all in field clothes, about him, he was ready for a trip to some interesting part of the state.—GEORGE MIKSCH SUTTON.

REVIEW

Wild America. By Roger Tory Peterson and James Fisher. Houghton Mifflin Company, Boston. xii+434, illus. 1955. $5.00

This is one of the most interesting and readable books I have seen on the American out-of-doors. It should be, for it is a product of the combined talents of two of the world's most successful publicizers of natural history. To millions who use his bird guides, the name Peterson is a by-word on this side of the Atlantic. Fisher is equally well known in Great Britain through his books and BBC broadcasts.

Wild America describes many of North America's areas of outstanding beauty and interest as seen in the course of a 30,000-mile odyssey that began in Newfoundland in April and ended July 12, 1953, with the parting of the two travelers on St. Paul Island in the Pribilofs. James Fisher was seeing America for the first time, and his guide was one who had scoured this part of the world in his ornithological studies. The writing is passed back and forth between them, in the form of edited notebook entries. It loses nothing by this treatment, being always fresh and fast-moving.

The reader will not go far in this volume without realizing that he is in the presence of the most hardened of bird watchers. From Newfoundland to the Smokies, to the Dry Tortugas, Avery Island, the Mexican cloud forests, Tule Lake, Olympic Peninsula, and the Pribilofs—the avifauna literally had no place to hide. Each species and subspecies was relentlessly brought to bay and consigned to the notebooks. The California condor almost escaped, but it too became a last-moment statistic.

The result was a deliberate and premeditated wrecking of previous records for birds listed in a 12-month period. At the end of the year, Peterson had tallied 572 species north of the Mexican border, comfortably blanketing the old record of 497. Including Europe and Mexico, Fisher had seen 718 species. On the American trip he saw 401 species that were new to him.

Because of its authoritative treatment of bird life, the book will be especially welcome to amateur ornithologists, but this subject does not monopolize the work. The thumbnail sketches of scenic and historic wonders are packed with solid information. Worthy of particular mention are the accounts of pueblo-dwelling and other southwestern Indians, the Olympic rain forest, and the fur seals.

Here and there, the authors gently point the way to conservation policy, but this was not intended to be a critical work. In fact, James Fisher, enamored of what he saw, credits us too much. We have had the power to ravage our wild America, he says, but instead have made it a garden. One reflects that the northern everglades, around Okeechobee, will not be long as these travelers saw them, for the draglines are busy.

No doubt Fisher was writing in part for the people back home, hoping to stimulate more attention to outdoor values in Great Britain. It would not have served that purpose to dwell on our errors. We wish him well—and hope that no Americans will be lulled into complacency by his generous words.

Wild America is beautifully illustrated throughout with Peterson's scratch-board sketches. From any standpoint, it is a thoroughly professional and satisfying job. The publisher is to be congratulated in producing this handsome volume of 434 pages for $5.00. It is no hazard to predict that sales will reward this confidence.—DURWARD L. ALLEN.

BRIEFER ARTICLES

INCIDENCE OF CRIPPLING LOSS IN STEEL TRAPPING

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The steel trap, second only to the gun, is man's favorite tool for taking small mammals. Where certain species of fur bearers are concerned, even more are taken by steel traps than by guns. Considerable attention has been given gun crippling, but little to the corresponding crippling by traps. Trap crippling figures are of interest to game managers since they must be taken into consideration in setting removal quotas and in computing total removal.

In addition to the species of animal trapped, many other factors influence the degree of crippling. These include the skill of the trapper, size and type of traps used, weather and terrain.

A trapping program was started on the Wheeler National Wildlife Refuge in the fall of 1949 and continued through the end of the legal fur trapping season in February 1955. Wheeler is primarily a waterfowl refuge, administered by the U. S. Fish and Wildlife Service. It is located in the Tennessee

River Valley of northern Alabama and covers approximately 41,000 acres of farm land, slough, and woodland.

A high population of potentially predatory small mammals made control through trapping desirable. From 12 to 18 trapping permits were issued each season to local men. These men trapped from the beginning of the Alabama fur season in late November or early December until the end of this season on February 20. In skill and experience they varied from comparative amateurs to semi-professionals. The most common trap used was the long-spring, size 1½, although sizes varied from No. 1 to No. 3, and types included coil-spring, long-spring, jump, single jaw, double jaw, and high-grip traps. Throughout the trapping period there was a wide variety of water and weather conditions.

During the 1949–50 and the 1950–51 trapping seasons, it became obvious that there was considerable loss through crippling, although no figures were kept. Since trappers were selected, operated under permit, and were subject to fairly close supervision, it was considered practical to assemble data on crippling losses. Trappers were asked to report all crippling. For the purposes of this study, all animals were considered crippled that pulled out of traps, escaped by wringing off or gnawing off feet, or escaped with traps. Tracks, hair, and other sign usually made it possible to determine the species of animal that escaped. The following information resulted:

There were 209 mink caught during the four-season study and an additional 79 crippled. This would give a crippling percentage of approximately 27.6. It was noted that the amount of crippling was low for shoreline sets, placed so as to drown the animals; higher for upland sets. While mink seldom gnaw off feet, they often wring them off.

The raccoon catch totalled 429, with an additional 137 crippled, giving a crippling percentage of approximately 24.

In addition to the 962 opossums trapped, 19 were crippled, or approximately 1.9 per cent. This low figure is due to the docile nature of these animals.

There were 90 striped skunks taken and only two crippled, a percentage of 2.1. As with opossums, these animals are docile and make no strenuous effort to escape.

There were 85 red and 111 gray foxes trapped during the study. It was not considered practical to try to separate crippling for the two species, since sign is often confusing. In addition to the 196 foxes caught, 69 were crippled, or 26 per cent. Since trappers in this section favor small traps, this figure may be abnormally high. Information gathered in projects involving the use of steel traps to live-trap fur bearers for restocking purposes has shown that a high percentage of the trapped animals die.

There is no way of computing the percentage of recoveries among these crippled animals, but some do recover. Those that pull out or lose only one or two toes are seldom seriously hurt. Those that lose feet are badly handicapped, but even these recover at times. Animals bearing old trap scars or with toes missing are frequently retrapped. Three-legged reccoons and mink are sometimes retrapped, although opossums, foxes, and skunks seldom recover from the loss of a foot.

Since the above study covered a four-year period, involving individuals with varied degrees of trapping skill, various trap sizes and types, and varying weather conditions, the percentages given should be fairly indicative.

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TRAPPING AND TAGGING MOOSE ON WINTER RANGE

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For two years this Division has trapped and tagged moose on winter range in Wells Gray Park. This preliminary note describes the techniques used. Trapping moose has not been found difficult, and others engaged in moose studies which would be aided by tagged animals may be encouraged by our success.

The herd involved is migratory along much of the Clearwater Valley in fall, winter, and spring. Population densities are high on the winter range (Edwards, 1952, 1954). This seasonal concentration is an important factor in our trapping success. Migration is an additional aid, for while some captures have resulted from drives to the traps, they usually captured migrating animals which entered of their own accord.

The traps are located on a low ridge which parallels the long axis of the valley. Their precise location was governed by winter observations on locally favoured migration routes, with the result that the traps and their leads are thrown across a route of concentrated movement. When the traps are set, gates at either end are open. Their entrances are camouflaged with evergreen boughs and appear as passages through the barrier to migration formed by the leads.

The first trap was made in the fall of 1953 at a total cost of about $200 which was mainly for

labour. This trap is octagonal in shape and might be more appropriately called a corral. The enclosed space is about 20 yards across. The sides are 25 feet long and 8 feet high. Two gates 10 feet wide can be raised 8 feet from the ground.

Construction is of horizontal aspen poles between split cedar posts. Posts are double, both at the eight corners and midway between these. The trap was constructed in an aspen stand providing abundant material for poles.

The gates are raised and one is held in place by a wooden lever. The trap is set so that moose walk into a length of nylon monofilament at the center of the enclosure. This moves a notched iron lever, which in turn releases the lever supporting one gate. As this gate falls, a rope attached to it releases a clevis pin supporting the other gate.

A chute, "V" shaped, with a wide mouth in plan, is used to hold the animals for tagging.

Experience with this trap shows that it is unnecessarily large for tagging operations. There is so much space within it that it is difficult to drive some animals into the squeeze chute. The large size is necessary, however, so the trap can double as a holding corral for anticipated experiments with captive moose.

Long lead fences of aspen poles wired to "A" frames, also of aspen poles, act as funnels to each gate. A total of 3,870 feet of leads has been constructed.

In the fall of 1954 two smaller traps were placed in the leads to the large trap. These are about 23 feet long by 5 feet wide, with sides and gates constructed much as for the larger trap. These traps cost about $100 each. Animals are held in one end of the trap for tagging by a swinging gate and squeezed by a movable panel. This panel is made of 2″ planking and swings on a heavy cedar log resting on the floor of the trap. It can be moved to the side of the trap when not in use.

The tags and plastic markers used have been described by Leopold *et al.* (1951). The plastic is cellulose acetate, .025 inch thick. Of five colors used, visibility under field conditions is best for red and pink, intermediate for blue and green, poorest for white. Simple tests have shown that both red and pink fade badly in direct sunlight. While this plastic is tough, one of three returns had lost the plastic marker. This material becomes brittle in cold and the markers may be lost in sub-zero winter weather. Tagging is done from outside or above the squeeze while reaching through the side or top. The operation is completed most successfully from a position above and behind the animal's head. When approached from the side or front, frightened animals struggle violently.

Trapped moose try to go over the fence only three or four times on the average, then run about the big trap. Fear and exhertion combine to tire the animals rapidly. Many soon exhibit defiant behaviour and charge at people on or near the trap walls. Some even return to attack after being released from the trap.

One moose has escaped from this trap by breaking a top rail and jumping out. Packed snow in the corral provided good footing and the animal scrambled over the height of 6′8″. No moose has yet gone over eight foot sides. In their jumping attempts they rarely get their hind feet off the ground. By contrast, mule deer that have been trapped come within inches of clearing the sides and make many more attempts to escape.

In 1954, twenty moose and three deer were trapped in four months (January to early May) during a period of increased trap efficiency from accumulating trapping experience. In 1955, the large trap took 25 moose and 2 deer, the small traps 15 moose. Poorer success from the small traps was expected. The lead fences converge on the large trap while the small ones are set in these leads.

A total of four calf moose and two adults have not survived. This is 10 per cent of the total captured. Two calves were trampled by cows, one strangled when roped, and one was struck by a dropping gate. One adult apparently died of fright and one broke a leg while leaving the corral.

In addition to trapped animals 17 recently born moose calves have been tagged in the past five years. This activity has been found too dangerous for field men working alone. We now search favoured calving grounds in teams of two or three. Cows are frightened from their calves with shouts and rifle shots into the air. A dog aids in pursuing active calves. Since beginning this method we have had no serious trouble from females protecting their young.

There are no returns or observations on moose tagged as calves, except for recaptures of calves recently tagged. Considerable evidence shows that cows and tagged calves are soon reunited so that separation of calf from cow does not seem to have a serious effect upon calf survival. Of trapped moose, none has repeated in the traps, one has been shot by a hunter, and two have been identified by field observers. In a number of cases, moose seen in the field have been suspected of carrying tags, but conditions for observation were not favourable enough for observers to be certain.

Enthusiastic assistance in all aspects of this project was given by L. E. Cook and C. Gaglardi, B. C. Forest Service; and by T. Helset and R. Helset who have given time freely on many occasions.

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DIFFERENTIAL TRAPABILITY OF RATS ACCORDING TO SIZE AND SEX

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The data presented in this paper concern the problem of differences among individual animals in their likelihood to be captured. Specifically the data compare the proportion of males and females, and of large and small rats caught in the early part of a trapping period with the proportion caught in the late part. Such comparisons are important in evaluating data on the composition of populations for if one sex or size group tends to enter traps more readily than the other, then a small sample period may give biased ratios.

Data to be satisfactory for testing differential trapability in this manner should include records on essentially all members of a population and should be collected within a period short enough to exclude the possibility of complications of natural turnover by reproduction, mortality, ingress and egress. Suitable data were obtained for this report from a series of populations of Norway rats (*Rattus norvegicus*) in Baltimore, Maryland, in 1943–44. City blocks, subsequently shown to support distinct and essentially isolated rat populations (Emlen, Stokes, and Winsor, 1948. Ecol. 29: 133–145) were trapped intensively until the discontinuance of fresh sign indicated complete removal. This trapping generally required less than two weeks. The catch of rats was examined and listed each day according to sex and three size classes (less than 100 grams, 100–250 grams, and more than 250 grams). These weight classes essentially represented immature, young adult and old adult age classes respectively. A total of 69 blocks was involved in the trapping but only 20 blocks have been used for this analysis. The other 49 blocks produced too few rats (less than 50) or had gaps in the record.

To check for differences in trapability the rats in each block were divided into two groups: those caught in the first third of the trapping period and those caught in the last two-thirds. This particular division was somewhat arbitrary but was superior to a division into halves by time which resulted in so few rats in the "last half" group that comparisons were meaningless or a division into halves by rat numbers which meant that only the first two or three days would be compared with the other 8–12 days of trapping.

To compare the proportions the percentages in the first part were contrasted with those in the second part of trapping. Since the same rats are not in each part these samples are independent. It would be possible to compare the first part with the whole (the percentages for all the rats) because by algebraic manipulation it can be shown that the formulae are equivalent but these values are not independent.

To compare the significance of the difference of two percentages the following formula was used

$$\frac{P_1 - P_2}{\sqrt{\frac{(PQ)}{n_1} + \frac{(PQ)}{n_2}}}$$

In this case the subscripts refer to each sample and P and Q refer to the pooled percentages for both samples.

The data are tabulated in Table 1 according to sex and size (age) groups. The first two columns give the number of rats of each sex and size in each time period. The third column (under each time period) gives the percentage of males in that size-class caught in the time period. For example, 398 large males and 348 large females were caught in the first third. Hence the percentage of males is 398/746 = 53.4. The fourth column gives the percentage for each size group according to sex. For example 398 large males were caught in a total of 812 male rats. Hence the percentage of large males caught in the first third was 398/812 = 49.0.

TABLE 1.—COMPOSITION OF POPULATION SAMPLES TAKEN DURING THE FIRST THIRD AND THE SECOND TWO-THIRDS OF INTENSIVE TRAPPING CAMPAIGNS IN 20 CITY BLOCKS. DIFFERENCES BETWEEN CORRESPONDING FIGURES IN THE FIRST AND SECOND PERIODS ARE SIGNIFICANT AT THE 5% LEVEL FOR ALL PER CENT FIGURES MARKED WITH AN ASTERISK

FIRST THIRD OF TRAPPING PERIOD

Size in grams	Males	Females	Per cent Male	Per cent by Size: Males	Per cent by Size: Females
250 +	398	348	53.4	49.0*	41.8*
100–250	292	359	44.8*	36.0	43.2
− 100	122	124	49.7	15.0*	14.8*
	812	831	49.4	...	...

LAST TWO-THIRDS OF TRAPPING PERIOD

Size in grams	Males	Females	Per cent Male	Per cent by Size: Males	Per cent by Size: Females
250 +	153	120	56.1	35.2*	30.6*
100–250	164	152	51.8*	37.7	38.8
− 100	119	119	50.0	27.0*	30.4*
	435	391	52.8	...	...

The fifth column gives corresponding percentages for the females.

The comparisons are naturally between the percentages in the first third and in the last two-thirds. Five of the pertinent comparisons were significant at the five per cent level: (1) the percentage of medium (100–250 gms) males (44.8 and 51.8); (2) the percentage by size for large-sized males (49.0 and 35.2); (3) the percentages for large females (41.8 and 30.6); (4) the percentages for small males (15.0 and 27.0); (5) the percentages for small females (14.8 and 30.4). From these results it seems valid to conclude that large rats tend to be caught before the small rats. The data for sex differences do not permit the conclusion that males tend to be caught before females, even though one of the differences is statistically significant. The comparison of rats over 100 grams and rats under 100 grams is not significant. Tests run on the detailed data for individual block populations showed a significant difference in favor of female in only two-thirds of the block populations.

The evidence that large rats are trapped sooner than small rats is quite convincing for both sexes. Large rats outnumbered small rats 3 to 1 in the first period but scarcely at all in the second. This principle applied in greater or lesser degree in all of the block populations studied. It would appear to be a factor of importance in evaluating age ratio data from incompletely sampled populations.

SUMMARY

Data on 2469 Norway rats caught in 20 city blocks in Baltimore, Maryland showed that in the first third of the trapping period large rats were markedly more trapable than small in the early stages of exhaustive trapping campaigns of about two weeks duration. These observations suggest that conclusions about size composition results based on samples may be unreliable.

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CONDUCTING DEER STUDIES WITH THE USE OF A HELICOPTER

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All known methods of determining big game populations have limitations which affect their usefulness. The commonly used airplane count cannot be relied upon to give accurate results when used over brush or timbered country, because the speed necessary for safety and maneuverability does not permit close observation of animals. Deer drives, using large crews of men, are expensive and time consuming. The use of horses on strip counts involves too much time and man-power and in dense cover the results obtained are not satisfactory. The pellet count method is as yet not entirely reliable because of the variables involved.

At present, few helicopters are available for conducting game studies, largely because the initial cost prohibits most wildlife agencies from purchasing and maintaining them for their exclusive use.

The H-13 Bell reconnaisance-type helicopter costs from $27,000 to $31,000 depending on what additional accessory equipment is obtained for use on the helicopter, such as radio and navigational equipment. This machine with two fuel tanks carries a gasoline load of 42 U. S. gallons. It consumes this fuel at the rate of 13 to 15 gallons per hour, and has a maximum range of 215 miles. Slow speeds of 12 to 15 miles are recommended with top speeds of around 90 miles. The oil capacity is 12 quarts, using approximately one quart for every two hours of normal operation.

The helicopter is not equipped with nor designed for instrument flying, therefore all day and night flying should be made under VFR conditions. It is hazardous to fly the H-13 Bell reconnaisance helicopter in winds that exceed 40 miles per hour or in gust spreads in excess of 24 miles. When icing conditions are prevalent, it is dangerous to operate the helicopter. Under these conditions the machine should not be flown faster than 12 to 15 miles per hour when out of ground effect.

It is not known what charge is made for the services of a pilot, but it costs from $70.00 to $100.00 an hour for pilot training at most civilian aeronautical schools. It requires at least 60 hours of flight training to meet the bare requirements or specifications set up by the C. A. A. Thus if a state game department wished to procure a helicopter for its official use and in addition, pay for the training of a member of its staff as a pilot, it would require an initial outlay of approximately $35,000.00. Commercial helicopters with a pilot can be rented for a flat rate of about $85.00 per hour. The Bell reconnaisance type of helicopter is well adapted for any elevational flying up to 9,000 feet and can operate successfully to an elevation of 13,000 feet.

The chief advantage of using one of the several makes of light aircraft is the initial cost and a higher rate of speed when speed is needed, other than that, the helicopter is capable of performing much more effectively in making game counts or range surveys over almost all types of terrain and ground cover.

The author was fortunate in being invited to make

a deer survey on the Fort Sill military reservation in Oklahoma, where a helicopter was furnished by the Military and used for three days while the survey was being made. Both the single and double propeller type helicopters were tried out. The flying was done over the low range of hills as well as the flat open country within the reservation. Under these conditions the helicopter performed perfectly at high as well as low elevations. This survey was made in November at a time when the leaves were falling.

During the three days while flying in the morning and evening hours in an attempt to make a population count of the deer on the military reservation, a total of 596 deer were counted. Of this number 23.5 per cent were bucks, 54 per cent does and 22.5 per cent were classed as fawns. It was estimated that about $\frac{3}{4}$ of the entire reservation was covered.

The single propeller type of helicopter is best suited for making big game counts because of its maneuverability. It can be flown slowly and can hover when necessary. It can be flown with comparable safety at much lower elevations than an airplane. Over brushy areas the helicopter can cruise just above tree-top level, which affords an opportunity for the observer not only to count animals, but to make sex and age class determinations as well. When flying just above tree-top level, the down draft from the propeller is strong enough to cause the animals to move about thus making it easier for the observer to get a more complete count than would be possible if the animals were lying down or standing still. The dome-like plexiglass front on the helicopter gives the observer a chance to see ahead, below, and to each side as the machine moves ahead. If and when it is desirable to make detailed observations on groups of animals, the helicopter can be turned easily and readily to re-circle the group below. When flying over open country, the helicopter can be elevated to higher than tree-top level and progress ahead speeded up, thus cutting down on the time element required to cover the area being censused. Refueling helicopters has to be done approximately every two to three hours of flying time.

If one wishes to make on-the-spot ground observations, such as on dead animals, browse utilizations, etc., the helicopter can be easily and quickly set down on any relatively level open spot, even if it is only an opening 100 feet in diameter.

The helicopter has been effectively used at Fort Sill, Oklahoma to patrol and apprehend game violators during the open deer hunting season on the reservation.

Like any other method of making game counts, the use of the helicopter gives best results during the time when leaves have fallen from trees and brush.

Under most conditions, early morning and evening hours are best for observing deer or elk, as it is during these hours that the animals tend to be out in open country. Attempting to count these animals between 9:30 A.M. and 4:00 P.M. when they are occupying the brush or timber lands adds to the difficulties in getting accurate results.

On days when strong winds are blowing, it is impracticable to attempt to count deer, as these animals invariably seek the protection of heavy cover and are thus more difficult to locate.

The author is indebted to Colonel C. W. Stratton, Headquarters Artillery School Command and Lt. Colonel Charles Ernest, Director of the Army Aviation School, Fort Sill, Oklahoma for much of the helicopter data used in the preparation of this paper.

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MARKER FOR GAME BIRDS

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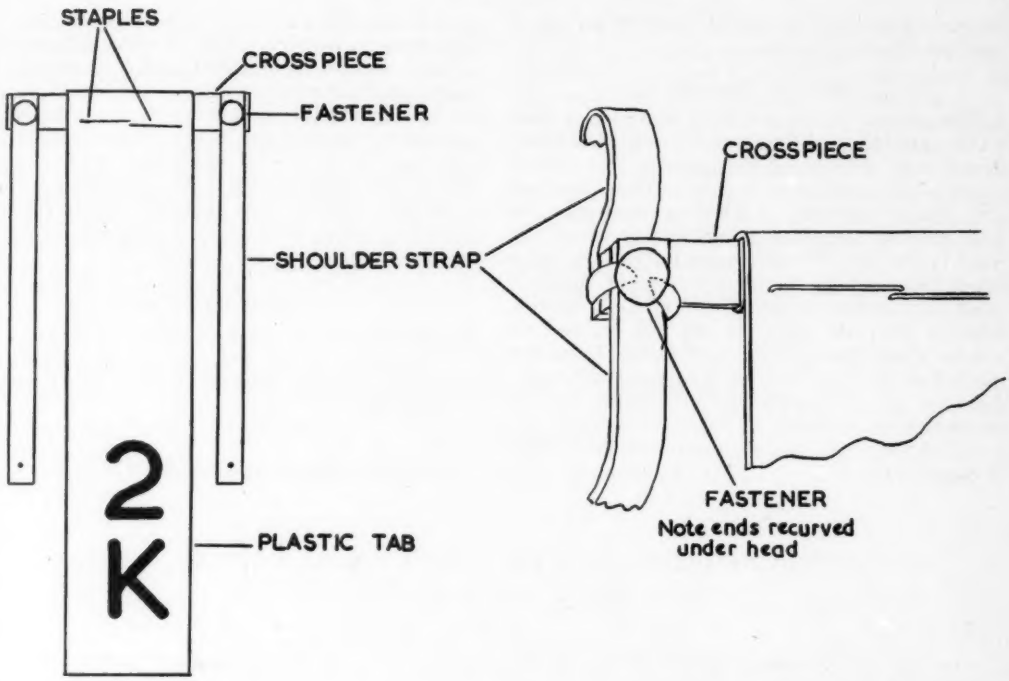
Census work on a population of partridges (*Perdix p. perdix*) at the I.C.I. Game Research Station at Fordingbridge, Hampshire, England, confirmed Middleton's (1935) observations that, in addition to the partridges shot, a large number disappear between September and the following March. While part of this loss could be accounted for by mortality factors, some of it was thought to be due to movements of birds at the time of covey break-up (January to early March). The study of this problem necessitated the development of a marking device which would be reliable for periods of from six to nine months (large-scale trapping is most easily carried out in September), render the birds individually recognisable at ranges up to 150 yards, and not affect their normal behaviour and survival. Speed of application, although a consideration, was not of very great importance.

After a period of experimenting with many different devices, a marker was developed which has been used for over four years, and has proved highly satisfactory. Recognition of individual birds is possible, with binoculars or telescope, at ranges up to 100 yards, and reliability for twelve month periods is almost one hundred per cent certain. Behaviour and survival both appear to be un-



TAB PREPARED FOR USE.

DIAGRAM TO SHOW METHOD OF SECURING FASTENERS.

FIG. 1

affected.

Although the study involving the use of these markers is still proceeding, it was thought that the method might be of use to other game biologists who need more permanent markers than those generally used.

DESCRIPTION OF MARKER

The marking device (Fig. 1) consists of a lettered and/or numbered plastic tab, which lies flat on the partridge's back and is held in position by means of a soft leather harness.

(1) Plastic Tab. This is made from a strip of polyvinyl chloride plastic (trade name "Welvic") 12.5 cms. long and 2.5 cms. wide. Numbers and letters are painted on with Vynafor Printing Black LBS paste. Only the last 5 cms. of the tab are used for this purpose, since this is the most easily observed region of the tab when partridges are feeding. The plastic can be obtained in a wide colour range, and in various thicknesses and degrees of plasticity. After extensive trials, plastic strips, technically described as "P.V.C. compound of Shore hardness 80 in sheets 0.02" thickness," were found to be the most suitable.

(2) Leather Harness. Full chrome horse hide, approximately 1.5 mm. in thickness, resisting any tendency to shrink or harden, is the most suitable material. Each "harness" consists of one "cross-piece" 50 x 7 mm., and two "shoulder-straps" 80 x 5 mm. The lengths of these strips are critical, since shorter strips may restrict flight, and longer ones may allow the bird to push its head under the cross-piece and the tab then hangs down in front of the bird's breast. The plastic tab is turned around the cross-piece and secured by two metal staples (as supplied for paper stapling). A hole is punched (by means of a chick toe-punch) 4 mm. from each end of the cross-piece and the shoulder straps. Brass paper fasteners (of the "split" type) are then pushed down through one hole in each shoulder strap and through the hole at each end of the cross-piece. The "tab" is now ready for use.

(3) Application. While an assistant holds the partridge, the made-up tab is laid on the partridge's back, the cross-piece lying between the wing bases. The free end of each shoulder strap is then passed behind and under each wing to be fixed by the paper fastener already holding the cross-piece to the shoulder straps. Using a pair of narrow-nosed pliers, the ends of the fasteners are opened out and recurved to fit snugly under the head of each

fastener. With practice, the whole operation should take less than one minute.

GENERAL REMARKS

The marking device has been developed for use on the partridge, and the dimensions stated are those found most suitable for that species. The harness will fit adults and juveniles not less than ten weeks old. (Using harnesses of different dimensions, we have marked pheasants (*Phasianus* sp.) and red-legged partridges (*Alectoris rufa*) in this way, while Macintosh (*in litt.*) has recently marked Gambel's quail in Arizona. It would, however, be unwise, without adequate trials, to use this method on species which undergo prolonged flights. From this method of marking we have obtained much useful data on the movements, pairing habits, etc., of partridges. Incidentally, we were able to prove that a cock red-legged partridge alone incubated a clutch of eggs in 1953.

Although the tabs have been subjected to wide variations in weather conditions (including periods of snow and frost), reliability might be affected by temperature extremes in other countries. While the plastic tab will last at least two years, the leather harness deteriorates after about fifteen months, and breakages occur in the cross-piece. It is possible that where extreme variations in temperature occur, a polythene plastic may be more suitable, and if more than a year's reliability is required, a thicker, tougher cross-piece could be used.

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Accepted for publication July 1, 1955.

AN UNEXPLAINED MORTALITY OF CANADA GEESE IN NORTH FLORIDA

G. D. Grice, Jr., Florida State University,
E. L. Tyson and E. B. Chamberlain, Jr.
Game and Fresh Water Fish Commission, Tallahassee, Florida

In February, 1954, the death of a number of Canada geese was discovered in the vicinity of a pond about twelve miles north of Tallahassee. This note is based on information obtained on several visits made to Huggle Pond, chiefly in February, March, and April.

The pond area was approximately five acres and it did not exceed two feet in depth. A wide mucky shoreline and the height of a former dike indicated that the pond was gradually receding. It has now all but disappeared (July 1955).

The first evidence of the goose die-off was found after a brush fire on February 10 when several charred geese carcasses were observed. In the vicinity of the pond on February 25 were 112 dead geese; 10 geese active but not capable of flight; and 25 geese able to fly for short distances. A flight of apparently normal wood ducks was observed on the pond, and a few small fishes (*Gambusia affinis*) and a number of tadpoles were seen in the water on this date. Several additional sick and recently dead birds were observed during subsequent visits to the pond at least until March 7. Thereafter no live geese were seen in the area.

The pH of the water on February 24 was 7.4, and calcium carbonate content was 11.0 p.p.m.

Numerous dinoflagellates (identified by John Howell as *Peridinium volzi* Lemmerman) were accidentally encountered in a liter water sample collected on February 25. Quantitative water samples and water temperatures were taken on all subsequent visits to Huggle Pond. The number of these organisms and water temperatures is given in Table 1. Water samples were taken from four other ponds and lakes in the area (one of which had geese on it), but no trace of *P. volzi* was found. A further indication of the intensity of the dinoflagellate bloom is evident from a pigment analysis by Nelson Marshall of Huggle Pond water (February 25) compared to another pond in the area. The reading for Huggle Pond was 112, compared to 7.1 mg. chlorophyll A per cubic meter of water for the other pond. Whether toxins were produced by such a bloom and if these could possibly be related to the death of the geese remains to be ascertained. The so-called "Red Tide," which periodically occurs along the west coast of Florida and which is accompanied by the death of large numbers of marine

TABLE 1.—NUMBERS OF *Peridinium volzi* AND WATER TEMPERATURES OF HUGGLE POND

Date	No. *P. volzi* per cc.	Water temp. (°C)
February 25	2738	10
March 1	2069	16
March 4	1627	15
March 7	1635	20
March 17	311	25
April 1	48	20
April 19	12	30

animals, is caused by a dinoflagellate, according to Gunter *et al.* (1948. Catastrophic mass mortality of marine animals and coincident phytoplankton bloom on the west coast of Florida, November 1946 to August 1947. Ecol. Monog. **18**: 309–324).

Mud and water samples were cultured by Dr. Annie L. Pates of the Department of Bacteriology of Florida State University. Tests for *Clostridium botulinum* were negative. Baby chicks were fed Huggle Pond water, and guinea pigs were injected with this water. Neither showed any ill effects. Two geese (one sick and one dead) were sent to the Patuxent Research Refuge for examination. Dr. C. M. Herman of this laboratory reported that nothing was observed in these geese which could explain the high mortality. He suggested fowl cholera as a possible cause. However, no unusual death of chickens or other farm fowl had occurred in the area.

Although these studies do not show what was responsible for the sudden mortality of the geese, it was felt that this incident should be reported in view of possible similar waterfowl mortality in other sections of the country.

Accepted for publication September 27, 1955.

A COLORED NECKBAND FOR MARKING BIRDS[1]

John J. Craighead

U. S. Fish and Wildlife Service, Missoula, Montana

and

Dwight S. Stockstad

Montana State Fish and Game Department, Missoula

In a long-range population study of Canada geese in the Flathead Valley of Montana, the need arose for a suitable marker to be used on large numbers of birds.

Data gathered to date indicate that the Flathead goose population is largely resident, presenting an unusual opportunity for studying the productivity of the population in relation to hunting losses and hunting pressure. A colored neckband was developed to facilitate determination of breeding age of the geese, whether the male becomes sexually mature before the female or vice versa, whether goslings produced in the Flathead Valley nest there later and whether some of these geese settle as nesting pairs in other areas. In addition, it was essential to determine precisely the relationship of subadult birds to adult birds in the population and to record movements and activity of subadult geese.

Numerous types of tags and markers were experimented with, including the plastic collars described by Helm (1955); neck tags as described by Taber (1949) and by Nelson (1955).

Tagging experiments were conducted on captive geese for a year and a half. The first objective was to find a simple neck loop that would not stretch, tighten, or break. Early experiments indicated a strap-type neck marker attached with the falconer's jesse knot would be satisfactory if a suitable material could be found. This material was found in plasticized poly vinyl chloride tape which was obtained from the Cee-Bee Manufacturing Co., 76 N. 4th St., Brooklyn 11, N. Y. Experiments with this plastic showed it would not harden unduly or become brittle at low temperatures and that it was exceptionally tough (manufacturer's specifications list an ultimate tensile strength of 2,000 psi). Markers of this material in use for eight months did not readily accumulate ice and exhibited no stretching, shrinking, or fading when exposed to the elements.

Tape one-half inch wide and .062 inches thick was utilized but wider tapes could be used to make combinations for identification of individual geese. Tapes thinner than .062 inches were not durable enough for long-term markers and thicker tapes were unnecessarily heavy and difficult to attach. The Cee-Bee Manufacturing Company can provide the tape in 24 colors in addition to black and white. Red, yellow, Nile green, orange, lilac, aqua blue, and white are easily visible.

The length of the neckband can be varied but twelve inches was found to be adequate for single-tail markers and fourteen inches for double-tail markers. Six inches between punch hole centers forms a loop that will accommodate a large gander and yet will not slip over the head of a well-feathered gosling.

Since large numbers of birds were to be neck-banded, it was essential to devise a band that could be applied quickly. Figure 1 shows the type

[1] Contribution from the Montana Cooperative Wildlife Research Unit; U. S. Fish and Wildlife Service, Montana State Fish and Game Department, Montana State University, and Wildlife Management Institute cooperating. The study was largely supported with Federal Aid in Wildlife Restoration funds under Pittman-Robertson Project W-71-R-1, the Montana State Fish and Game Department.

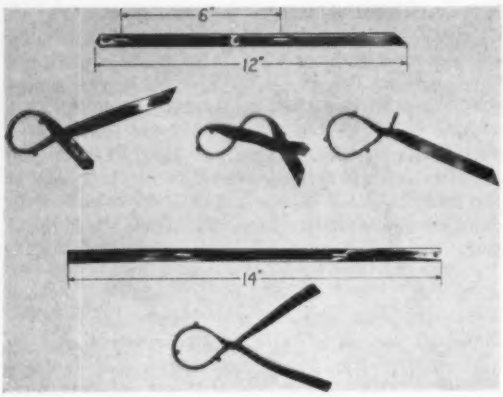

FIG. 1. Plastic Neck Marker; twelve-inch single-tail marker and fourteen-inch double-tail marker.

of neckband finally developed. Using the jesse knot, it can be put on a captive goose in from 15 to 30 seconds, which compares favorably with the time required to attach an aluminum leg band. This marker can be made readily in large quantities at a unit cost of less than six cents. A single neckband can be constructed in about 30 seconds and by using a template, five-eighth-inch oblong leather punch and a paper cutter they can be mass-produced in less time.

During the summer of 1955, 250 juvenile geese were leg banded and of these 245 were neckbanded. Five birds not color marked were goslings still in the down stage.

Of 75 banded and color marked geese that were shot and reported during the 1955 hunting season, all retained both the leg and neck bands.

Periodic ground and aerial censuses during summer and fall provided hundreds of identifications of neckbanded geese. The neckbands were visible from the census plane and on the ground they could readily be detected with the naked eye up to 150 yards. Binoculars or spotting scope increased the range of visibility to nearly one-half mile. Identifications were made of marked geese in flight, with the unaided eye and with binoculars. Hunters frequently reported seeing the colored bands on geese as they flew overhead.

Nearly 100 brood observations of marked and unmarked juveniles throughout the summer supported Helm's findings (1955) that neck markers on Canada geese had no lasting effect on behavior. During the 1955 hunting season, 497 goose flights were observed, comprising a total of 7300 geese. There was no indication that behavior patterns of individual geese or of flocks containing neck-banded individuals were affected by the marking.

Some captive geese have worn markers of this type for 18 months with no evidence of choking, compaction or feather wear. There have been no reports indicating such conditions occurred on the marked birds of the wild population.

During sub-zero weather an unverified report was received of a hunter finding a ball of ice on the tail of a neck marker. Experimental dipping of the markers in water at −15°F. failed to cause ice balls to form on the material. A thin glaze developed on the flat surfaces of the marker but failed to build up beyond the edge of the material and was easily dislodged by slight movement. The possible adverse effects of this neck band are being investigated further.

Use of this type of marker on other species of birds and mammals looks promising. Currently the marker or modifications of it are being tried on sage grouse, turkeys, magpies, birds of prey, deer, elk, and mountain sheep.

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Accepted for publication March 8, 1956.

EDITOR'S CONCLUDING NOTE

Publication of this issue winds up more than six years of editorial activity with the Journal. As Associate Editor with Gustav Swanson, and as Editor since April, 1953, I have enjoyed the task particularly because it has resulted in hundreds of most pleasant personal associations with authors, Associate Editors, Society Councils, Members who have expressed themselves concerning the Journal, and our printing staff. Special thanks are due the Associate Editors, R. W. Darrow, C. M. Herman, E. L. Kozicky and L. A. Krumholz. Dr. Krumholz has carried an extra heavy load, having edited all of the fisheries papers. For Journal weaknesses I humbly apologize, and express my gratitude for Members' patient encouragement.

The responsibility now goes to Dr. Joseph J. Hickey, whose great experience and capabilities are well known. Let us realize that as the Society and its Journal grows, so does the editorial job. Let us acknowledge that if the Journal is to satisfy the varied needs of the Membership, Dr. Hickey must have the support and assistance of every one of us.

—OLIVER H. HEWITT

THE WILDLIFE SOCIETY

Report of the Secretary-Treasurer for the Year 1955-56

The Society Continues to Grow

In its 19th year of existence The Wildlife Society continued to grow, the combined number of Members and Subscribers totaling nearly 3000 by the end of December, 1955. Growth was evidenced also by the increased numbers of invitations for the Society to be officially represented at national and international conservation meetings. A new Section—the Central Mountains and Plains Section—was approved by the Council. This group, and the older Sections, held meetings which were characterized by good attendance and well planned programs. Some of the relationships between the parent Society and the Sections are still in need of clarification, however. The revised By-Laws, which were approved by 1091 of 1131 voting members, require that Members of Sections must also be Members of the parent Society and that the Sections must adopt and be governed by all rules and regulations prescribed by the Council. An increase in annual dues to $6.00 was approved three to one (1173 to 391) by mail ballot. A uniform price of $2.00 per copy was established by the Council for all available back issues of the Journal. The added income should meet increased printing costs, permit enlargement of the Journal and enable the Society to engage more effectively in other activities.

As of the end of December, 1955 we had 2547 Members and 429 Subscribers. Memberships for four successive years are shown below:

Class of Membership	Number of paid-up Members at the close of December:			
	1952	1953	1954	1955
Honorary	11	13	15	17
Life	10	10	17	27
Regular	1919	2140	2346	2503
Subscribers	388	377	406	429
Total	2328	2540	2784	2976

New Members taken into the Society in 1955 numbered 318 compared with 374 in 1953, 424 in 1954, and to date for 1956, 101. As of the end of February 1956, we had 2082 paid-up members. We are running slightly behind, both in number of new members, and in percentage of membership renewals as compared with last year at this time.

The deaths of the following Members are reported with regret: William R. Bergeson, Merritt A. Edson, R. W. Eschmeyer, Dave Harris, Gardiner F. Jones, Richard C. Marzolf, John L. Nemes, Asa O. Weese and James W. Wheeler.

The demand for back issues of the Journal of Wildlife Management exceeded requests of the previous year, and by February 1, 1956, the following issues were out of print: Volume 1, Nos. 1 and 2; Volume 2, Nos. 2, 3 and 4; Volume 3, all issues; Volume 5, Nos. 3 and 4; Volume 7, Nos. 1 and 3; Volume 8, No. 1. Less than a dozen copies of nine other issues remain. When notified that the Society had but one complete set of the Journal (it being bound and used by the Editor) the Council authorized the Secretary-Treasurer to obtain two additional complete sets for Society use in case a Society Library is established and a full-time Secretary-Treasurer is employed. One such set was obtained in January.

Special Committees

An Index Committee consisting of Allen W. Stokes, Chairman, George H. Kelker, Jessop B. Low and Martin Laakso was appointed in January to prepare an index of Volumes 11 to 20 of the Journal of Wildlife Management.

Durward L. Allen, Kenneth D. Carlander, Ian McT. Cowan, Ben Glading and Paul Hickie, all previously members of various Awards Committees, constituted a Committee on Awards Procedure. They drew up statements on policy and procedure which have been duplicated and will be of use to Committees on Awards for wildlife and fisheries publications, conservation education, and for selecting recipients for the Leopold Medal.

The By-Laws Revision Committee, consisting of Shaler Aldous, C. H. D. Clarke

and C. R. Gutermuth, Chairman, redrafted the By-Laws, which were approved by the Council and, later, by the membership, as indicated above, in response to a mail ballot. Apparently the minority who voted against the By-Laws objected primarily to (1) making the Secretary-Treasurer (a part-time, paid employee selected by the Council) a voting member of the Council and (2) the provision that the By-Laws can be amended by a majority vote of the Members present at a meeting of the Society even if previous notice of the proposed changes has been given to the membership.

Past President Gustav Swanson was requested to study and report on costs for special publications. During the year some interest was shown in the possibility of the Society's preparation and publication of books, manuals or bulletins on (1) wildlife management techniques and (2) writing.

A committee consisting of David Munro, Paul Needham, Arnold Nelson, M. O. Steen and S. C. Whitlock, Chairman, gave some consideration to the question of transplanting exotic animals.

AFFILIATIONS AND REPRESENTATION AT MEETINGS

The Society maintained its affiliations with the International Union for the Protection of Nature and the Natural Resources Council of America. A Society Member, Richard W. Westwood, is Chairman of a newly established Commission of Public Information of the I.U.P.N. at 1214 Sixteenth Street, Washington 6, D. C. Gustav Swanson was the Society's official representative. Your Secretary represented the Wildlife Society at the annual meeting of the Natural Resources Council of America held at Silver Springs, Florida, October 6, 1955. A book on the management of renewable natural resources is being sponsored by this Council. Several of the authors are Wildlife Society members.

Your Secretary also represented the Society at the Second National Watershed Congress held in Washington, D. C., December 5 and 6, and is pleased to report that more attention was devoted to wildlife than last year. Durward Allen presented a paper entitled, "Providing for maximum fish and wildlife management in a watershed program." The Secretary also attended, without cost to the Society, the meetings of the Western Association of State Game and Fish Commissioners, the International Association of Game, Fish and Conservation Commissioners, and the Southeastern Association of Game and Fish Commissioners, discussing Society affairs as time and opportunities were found to do so.

A. E. Borell officially represented the Society at the Arid Lands Conference sponsored by the A.A.A.S. and held in Albuquerque, New Mexico, April 26–29. Discussion Group No. 8 at this Conference, led by Walter P. Taylor, considered the topic "Importance of wildlife conservation in arid areas," and recommended that at future conferences more emphasis should be placed on recreational uses of arid lands.

John M. Anderson was the Society's delegate to the Waterfowl Advisory Committee Meeting held in August.

The Society maintained its participating membership (without dues) in the International Science Foundation, providing material for the "Handbook of the Scientific Resources of the San Francisco Bay Area." The I.S.F., a non-profit membership corporation, "represents a cooperative effort on the part of academies of science, engineering and scientific societies, colleges and universities, foundations, research institutes, industrial laboratories, corporations, financial institutions, and other organizations to develop a program which will stimulate direct working relationships between the United States scientists and their colleagues abroad."

NOMINATIONS AND ELECTION RESULTS

Tabulation of mail ballots for Regional Representatives showed the nominees to be as follows: Region I, Roger Latham and W. R. DeGarmo; Region II, Edward B. Chamberlain and C. Edward Carlson; Region III, Bill T. Crawford and Robert S. Campbell; Region IV, Lee E. Yeager and Ralph R. Hill; Region V, Wendell G. Swank and Fred M. Baumgartner; Region VI, A. Starker Leopold and J. B. Lauckhart; and Region VII, Ian McT. Cowan and Anton DeVos.

The Nominating Committee, under the Chairmanship of W. J. K. Harkness, nominated Durward L. Allen and Charles A. Dambach for President and John S. Gottschalk and Louis A. Krumholz for Vice-President. The election ballots were counted

and audited as prescribed by the By-Laws. The winning candidates were those named first in each of the offices listed above.

GENERAL ACTIVITIES

In an effort to handle Society business promptly and keep the records current, 44 press orders and a like number of bank deposits were made. More than 600 changes of address for members alone were recorded during the year. Routine duties of the Secretary included compiling the Membership List published in the October 1955 issue of the Journal, processing new memberships and subscriptions, handling dues payments, sending invoices to subscribers, distributing membership application blanks, working with the various Society committees, and answering requests for information on professional opportunities and training.

FINANCIAL REPORT

In presenting the financial statement of The Wildlife Society for the fiscal year 1955–56, it should be pointed out that the books were closed February 25, 1956 in order to permit an audit prior to the Annual Meeting. You are reminded, also, that the Secretary-Treasurer is bonded in the amount of $20,000 and that the stock of Journals held at Cayuga Press, Ithaca, New York, is insured in the amount of $6000 for fire and $6000 for sprinkler leakage with the Continental Insurance Company. The bond and insurance policies will be renewed in the amounts deemed advisable by the Council upon the expiration dates of the respective policies, August 24 and May 5, 1956.

ASSETS

Cash				
Checking Account (Bank of Silver Spring, Md.)			$11,528.99	
Savings Account (Bank of Silver Spring, Md.)			4,179.72	
Permanent Fund (Emigrant Ind. Savings Bk., N. Y.)			10,825.39	$26,534.10
Securities				
44 shares State Street Investment Corp.			1,716.00	
30 shares Loomis-Sayles Mutual Fund, Inc.			1,327.50	
U. S. Government Bonds Series G—12 yr. bonds				
Serial No.	*Cost*	*Date of Purchase*		
D-2576621G	500.00	April, 1947	485.00	
D-2576622G	500.00	April, 1947	485.00	
D-2943626G	500.00	Sept., 1948	480.50	
D-2943627G	500.00	Sept., 1948	480.50	4,974.50
Accounts Receivable			105.20	105.20
Total Assets				$31,613.80

LIABILITIES

Liabilities	None
Net Worth	31,613.80
Total Liabilities and Net Worth	$31,613.80

STATEMENT OF RECEIPTS AND DISBURSEMENTS

Bank Balance March 1, 1955			$23,492.83
Receipts (deposited to checking account)			
Dues	$13,748.00		
Subscriptions	2,606.42		
Sales:			
Back Issues, Journal	1,093.20		
Animal Cycle Symposium	49.00		
Farm Pond Symposium	18.00		
Ten-Year Index	20.99		
Membership List	2.00		
Miscellaneous	102.31*	$17,639.92	
Receipts (deposited to savings account)			
Dividends and Interest	664.64		
Life Membership Dues	625.00		
Gifts and/or Refunds	2.58	1,292.22	18,932.14
			$42,424.97

FINANCIAL REPORT (*continued*)

Disbursements			
Journal, Printing and Mailing (including Membership List)		11,818.54	
Mailing Back Issues of Journal, Reprints, Symposia		338.93	
News, Printing, Folding and Mailing		717.94	
Editors' Expenses		72.03	
General Supplies, Printing and Communications (including mailing ballots, dues notices, etc.)		1,024.34	
Executive Secretary			
Clerical Assistance	700.00		
Honorarium	700.00		
Travel and Meeting Expenses	10.00	1,410.00	
Refunds, Bank Charges, Bad Checks		43.90	
Affiliation Dues (I.U.P.N., Natural Resources Council)		100.00	
Meeting Expense (Employment Desk, Awards, etc.)		80.24	
Audit, 1954–55		30.00	
Back Issues; Reprints of Membership List		124.95	
Miscellaneous		130.00*	15,890.87
Bank Balance February 25, 1956**			$26,534.10

* Including $100 transferred to permanent savings account (Life Member).
** Books closed February 25, 1956 to permit auditing before Annual Meeting.

Respectfully submitted,

/s/ Daniel L. Leedy
DANIEL L. LEEDY, *Secretary-Treasurer*

REPORT OF THE WILDLIFE SOCIETY COUNCIL MEETING, MARCH 4, 1956

The Council met at 7:30 P.M., March 4 in the Jung Hotel, New Orleans, Louisiana. Members present were Justin W. Leonard, President; E. L. Cheatum, Vice-President; Gustav A. Swanson, Past-President; Daniel L. Leedy, Secretary-Treasurer; and Roger Latham, Leonard E. Foote, Don W. Douglass, Lee E. Yeager and Wendell Swank, Representatives of Regions 1, 2, 3, 4 and 5 respectively. Richard Taber officially represented Region 6 as Starker Leopold's alternate. Region 7 was not represented. Editors O. H. Hewitt and Tom Evans attended as advisors.

The Council accepted, with regret, Dr. Hewitt's decision to resign as Editor following publication of the July 1956 issue of the Journal of Wildlife Management. Ollie has served faithfully and well as Associate Editor and Editor respectively, each for terms of three years, and is deserving of the Society's sincere thanks. President Leonard appointed a committee consisting of Gustav A. Swanson, Chairman, Roger Latham and your Secretary-Treasurer to contact potential editors during the New Orleans meetings and report to the incoming Council any promising leads for a successor to Hewitt.

To distribute the work load and reduce the amount of time required by the Editor on Society publications, the Council agreed that up to four or more Associate Editors should be appointed. Gustav Swanson stated that President-Elect Durward Allen, who was unable to attend the meeting on account of illness, had asked him to be Chairman of a committee to investigate publication of special articles or works of monographic nature. Swanson suggested that a separate editorial staff might be appointed to edit any such special publications.

Editor Hewitt reported on the response to his preliminary announcement to conservation agencies concerning the Journal as a publication outlet for "paid articles" additional to those articles which normally would be included in the Journal. The announcement was received with enthusiasm by many of the state conservation department directors. Any additional articles received and accepted on this basis would serve to enlarge the Journal at no cost to the Society

and without crowding out other articles.

A discussion was held on ways and means of getting a better distribution of the proceedings of regional and sectional wildlife conferences, thus enabling Members to obtain copies of mimeographed and processed papers of interest without undue delay. The Editor of the Wildlife Society News was requested to carry notices of sectional meetings in the News, including such pertinent information as dates of meetings and whom to contact for details on cost and availability of the proceedings.

Although the Council did not encourage widespread use of photographs in obituary articles, it ruled that when photos were used, the Society should pay for them.

A request for a contribution of $100 to the Division of Biology, National Research Council, to help finance the distribution of a booklet on "Career Opportunities in Modern Biology" for use in highschool vocational guidance programs was tabled. Since little reference was made to wildlife management in this booklet the Council believed that the Wildlife Society might better prepare a leaflet on training and job opportunities in the wildlife field, and recommended that President-Elect Allen take steps to have such a leaflet prepared. The need for such a leaflet was recognized and it was believed that the cost of the publication could be covered by a nominal fee.

Continued affiliation with the I.U.P.N. and the Natural Resources Council of America was approved, including a $50 contribution to each. The Council also approved sponsorship ($10) of the Third National Watershed Congress and agreed that the Society should delegate one of its Members to the Waterfowl Advisory Committee if requested to do so. Affiliation at no cost to the Society was approved, also, for the National Research Council, the International Science Foundation, and the American Committee for International Wild Life Protection.

In general accordance with the recommendations of last year's Streamlining Committee, the Council, in considering the budget for 1956–57, authorized the Secretary-Treasurer to make reasonable and necessary transfers of funds between budget items other than fixed items so as to expedite the handling of routine affairs. A budget of $19,000 was approved as follows:

BUDGET FOR 1956–57

Journal of Wildlife Management	$13,500.00
Wildlife Society News	800.00
Mailing back issues, reprints, etc.	300.00
Editors' Expenses	150.00
General Supplies, printing, postage, express, (Including printing and mailing of ballots, dues notices, etc.)	1,300.00
Secretary-Treasurer:	
Clerical Assistance	700.00
Honorarium	700.00
Travel and Meeting Expenses	300.00
Affiliations (I.U.P.N., Natural Resources Council)	100.00
Meeting Expenses (Including Employment Desk, Awards, Delegate to Waterfowl Advisory Meeting, etc.)	150.00
Contingency Fund	340.00
Leopold Medals (10)	260.00
Insurance—Fire and Sprinkler Leakage for back issues (3 years) at $15,000	240.00
Fidelity Bond for $25,000 (3 years)	160.00
	$19,000.00

In recognition of their distinguished service and achievement in the fields of teaching and wildlife management Drs. P. F. English and George O. Hendrickson were recommended for Honorary Membership. Dr. E. R. Kalmbach was named as Trustee to succeed Herford Elliot. Tom Evans and Daniel Leedy were retained as Editor of The Wildlife Society News and Secretary-Treasurer, respectively.

Four resolutions submitted by Charles A. Dambach, Chairman of the Resolutions Committee, were approved for presentation to the Members in attendance at the annual business meeting.

Lee E. Yeager, Chairman of the Committee on Regions and Sections presented a report for Council use in drawing up rules and regulations called for in the By-Laws for governing Sections. Pertinent portions of this report, together with recommendations of the Minnesota Section concerning the recently approved By-Laws, will be referred to the Committee on By-Laws Revisions for their consideration and possible action by the Society. The tenure and method of nominating Regional Representatives were discussed with no definite recommendations for changes being made. Under the present method it is possible, although not probable, that all Council Members except the Past President could change from year to year.

The Secretary-Treasurer was instructed to continue the practice initiated during fiscal year 1955–56, of distributing to the membership biographical sketches of the nominees for President and Vice-President. Such sketches for Regional Representative nominees were not considered necessary. A proposal that a faint over-lay map showing regional boundaries be printed on election ballots for the convenience of Members in voting was tabled. The Secretary-Treasurer was authorized to have new award certificates prepared which would differentiate between publications in the fisheries and wildlife fields. He was also encouraged to obtain back issues, as the opportunity arose, to fill in missing numbers of the Journal in an effort to provide libraries with complete sets of the Journal. The Council recommended that two sets of the Journal be bound for official Society use and that two sets of the News be preserved.

The Council ruled that the Society's mailing stencils should not be used for mailing to the membership announcements of books, or for distributing brochures, propaganda and other materials by other societies or business firms.

DANIEL L. LEEDY,
Secretary-Treasurer

MINUTES OF THE ANNUAL MEETING, MARCH 5, 1956

The twentieth annual business meeting of the Wildlife Society was called to order by President Justin W. Leonard at 8:00 P.M. March 5, 1956, at the Jung Hotel, New Orleans, Louisiana. Approximately 100 Members were in attendance.

Minutes of the previous meeting were approved as published in the Journal of Wildlife Management 19(3): 391–393.

The Secretary-Treasurer then gave a synopsis of his report, referring the Members to the mimeographed report available in the meeting room for details on income and disbursement, and Society activities during the year.

The report of the Council Meeting held March 4 was read by the Secretary-Treasurer and the items requiring approval of a majority of the Members present at the business meeting were considered next, i.e., the election of Honorary Members and adoption of resolutions. Drs. P. F. English and George O. Hendrickson were elected to Honorary Membership, bringing the total of Honorary Members to 19. Resolutions were passed as follows:

1. WHEREAS, water pollution control is an activity of vital national significance, and

   WHEREAS, the Taft-Barkley Water Pollution Control Act of 1948 will expire on June 30, 1956, terminating the authority of the Department of Health, Education and Welfare to conduct research, undertake surveys, and enforce anti-pollution restrictions in interstate waters, and

   WHEREAS, there is now in the House of Representatives a bill, H.R. 9540, to revise and extend the national water pollution control program, now therefore,

   BE IT RESOLVED, that the Wildlife Society, in convention assembled this 5th day of March, 1956, does hereby urge the Congress to take immediate steps to enact a measure embracing the objectives of H.R. 9540, and to pass a supplementary appropriation so that this important work can be continued without interruption.

2. WHEREAS, the National Forests provided recreational opportunities for more than 40 million visitants in 1955, and

   WHEREAS, adequate funds have not been available to properly develop and maintain recreational facilities and wildlife habitat on National Forest Lands; now therefore,

   BE IT RESOLVED, that the Wildlife Society, in convention assembled this 5th day of March, 1956, does hereby endorse the principles of the Metcalf bill, H.R. 1823, as introduced in the 84th Congress, and

   BE IT FURTHER RESOLVED, that the Wildlife Society, in convention assembled this 5th day of March, 1956, urges the enactment of legislation that will earmark 10 per cent of the annual receipts from the national forests, but not to exceed $5,500,000 in any year, and make it available to the Secretary of Agriculture, for the above described purposes.

3. WHEREAS, the national wildlife refuge system has been invaluable in the preservation and perpetuation of certain endangered species of wildlife and of migratory forms, and

WHEREAS, there is now before the Merchant Marine and Fisheries Committee of the House of Representatives the Metcalf Bill, H.R. 5306, which would require the Secretary of the Interior to obtain prior approval from Congress before disposing of or relinquishing any part of a national wildlife refuge, and

WHEREAS, there also is pending in committee an amendment which would exempt the national wildlife refuges from presently applicable oil and gas leasing regulations except in time of national emergency and then only by direct Executive Order, now therefore,

BE IT RESOLVED, that the Wildlife Society, in convention assembled this 5th day of March, 1956, does hereby go on record as favoring the objectives of H.R. 5306 and recommends the attachment of a provision to exempt all of the national wildlife refuges from the existing oil and gas leasing regulations.

4. BE IT RESOLVED, that the Wildlife Society extend to the Wildlife Management Institute, to members of the Program Committee of the 21st North American Wildlife Conference and to the Jung Hotel of New Orleans, Louisiana, grateful appreciation for cooperation, facilities and courtesies that contributed to the success of the Society's annual meeting.

Reports of the Committees on Awards were then given, the signed certificates having been presented for the first time at the Society Dinner immediately preceding the Meeting. (As customary, presentation of the Leopold Medal was made at the annual banquet of the North American Wildlife Conference on March 6. Hoyes Lloyd was the recipient.) Reports of the Awards Committees are published in this issue of the Journal.

Dr. George A. Petrides, in presenting an abbreviated report of the Committee on Employment, pointed out that the complete Committee Report would be published in this issue of the Journal (See pages 342–344). Graduates at all levels for the school year 1954–55 totaled 421 compared with a high of 633 in 1949–50. The Committee recommended that tabulations of students and graduates be published yearly.

Norman G. Wilder, in presenting the report of the Committee on Job Standards, referred the Members to the processed Committee Report available at the Meeting and recommended that the Committee be discontinued until such time as the standards suggested in the report could be evaluated. The Committee had attempted to develop minimum professional standards for four types of jobs: Conservation Officer Assistant (Fish and Wildlife); Field Supervisor Assistant (Fish and Wildlife); Research Biologist Assistant (Fish and Wildlife); and Instructor, Wildlife Management. Major headings under each type of job included (1) Definition and Description of Duties; (2) Qualifications; (3) Examination Requirements—Method of Selection; (4) Training Requirements after Acceptance for Duty; (5) Leave; and (6) Compensation. The minimum salaries recommended for the first three jobs were $4200 per annum plus travel allowance; and $3900 per annum on a 9-month basis for the instructor, or $4500 per annum on a 12-month basis.

Bill T. Crawford, Chairman of the Membership Committee, reported that special letters were written to all delinquent 1955 Members pointing out the work and values of the Society and urging each to remain active in the Society. He stated that five regional and/or sectional conference desks were maintained during the year to focus attention on the Society, render service and promote new memberships. He urged that the many wildlife administrators who are not Members be encouraged to join the Society.

Chairman Louis A. Krumholz of the Terminology Committee reported that his Committee had reviewed more than 600 terms that had been submitted for consideration. The Committee had concluded that probably not more than 50 terms should be included in any final list that might be published—these to be terms which are commonly used or misused by Members of the Society and which are controversial or inadequately defined in the dictionary. However, Members were asked to submit any terms they believed should be considered by

the Committee in the interest of clarification and standardization.

In reporting on the work of the Committee on Transplantation of Exotic Animals, Chairman Stanley Whitlock advocated a middle-of-the-road, conservative approach to the problem, stating that the condemnation of all attempts to improve game conditions by importation or transplantation of exotics would get us nowhere. He recommended that the Committee be continued.

John M. Anderson reported on his attendance as the Society's representative at the meeting of the Waterfowl Advisory Committee in Washington, D. C., August 8 and 9, 1955. He stated that through the media of maps, charts, graphs, colored slides and detailed written summaries of data, more complete information on waterfowl production and supply was given each committee member than in previous years. He reported that the recommendations from the Waterfowl Advisory Committee were given full consideration by the Fish and Wildlife Service in promulgating regulations but noted reluctance on the part of delegates from various Flyway Councils to express personal opinions on matters not previously discussed at their respective council meetings.

The Secretary reported that he had attended the annual meeting of the Natural Resources Council at Silver Springs, Florida, October 6, 1955. This Council is sponsoring a book on the management of natural resources. Several of the authors are Wildlife Society Members. One of the Council's committees is investigating the Federal Lobbying Act and income-tax laws and regulations as they affect N.R.C. member organizations. The Committee report will be of interest to the Society in connection with the distribution of resolutions to members of Congress.

Although no meeting of the International Union for the Protection of Nature was held during the year, delegate Swanson stated that the next meeting would be held in Scotland this coming summer and he hoped some one would be able to represent the Society.

In Durward Allen's absence, the Secretary read the report of the Representative on the Division of Biology and Agriculture, National Research Council. The representative had served on the National Science Foundation Graduate Fellowship Evaluation Committee and reported that a Committee on Natural Resources had been set up within the Council's Division of Biology and Agriculture. Dr. Clarence Cottam is a member of this Committee.

A motion that the reports of the Regional Representatives be published in the Journal or the News was carried; hence, these reports were not given at the meeting.

Under new business, Dr. J. J. Hickey gave a brief report on the meeting held by wildlife teachers the previous evening. On the basis of discussions at that meeting Dr. Hickey moved that the incoming President appoint a General Editor to undertake the compilation of a manual on wildlife management techniques, the Editor to be assisted by an advisory committee composed of men with suitable experience in the techniques of management and representing diverse geographic and ecological areas. This was seconded by George A. Petrides. Following a discussion in which C. R. Gutermuth urged the Society to promote the publication of such manuals and guides to elevate the standards of the profession, providing any money necessary to prepare the publications, and in which E. L. Cheatum cautioned the Editor to draw lines on how far to go in the compilation of a techniques manual, the motion was carried with scarcely a dissenting vote.

As no additional business was brought up, President Leonard expressed his regrets that President-Elect Allen was unable to be present, thanked the officers and Members for their cooperation during the year, and called for a motion to adjourn. The meeting adjourned at 10:15 P.M.

DANIEL L. LEEDY,
Secretary-Treasurer

REPORT OF FISHERIES PUBLICATION AWARD COMMITTEE, MARCH, 1956

By unanimous vote of the committee, the award for 1954–55 goes to Leo Shapalov and Alan C. Taft, 1954, The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*). Calif. Dept. Fish and Game, Fish. Bull. 98: 1–375, figs. 1–32.

Among the other worthy publications considered, the following have been selected for honorable mention: Harriet B. Carlander, 1954, History of fish and fishing in the upper

Mississippi River. Upper Miss. Conservation Comm., 96 pp.; Kenneth Carlander, 1955, The standing crop of fish in lakes. Jour. Fish. Res. Bd. Can., 12(4): 543–570; Frances N. Clark and John C. Marr, 1955, Population dynamics of the Pacific sardine. Prog. Rept. Calif. Coop. Oceanic Fish. Inves., pages 11–48; Arthur D. Hasler, 1954, Odour perception and orientation in fishes. Jour. Fish. Res. Bd. Can., 11(2): 107–130; Romeo Mansueti and Haven Kolb, 1953, A historical review of the shad fisheries of North America. Chesapeake Biol. Lab., Publ. 97; Philip R. Nelson and W. T. Edmondson, 1955, Limnological effects of fertilizing Bare Lake, Alaska. U.S. Fish and Wildlife Service, Fish. Bull. 102: 415–436; Gerald B. Talbot, 1954, Factors associated with fluctuations in abundance of Hudson River shad. U.S. Fish and Wildlife Service, Fish. Bull. 101: 373–413.

We commend highly the efforts of the U. S. Fish and Wildlife Service initiating the publication of "Sport Fishing Abstracts."

ROBERT C. BALL
ROBERT S. CAMPBELL
WILLIS KING
RICHARD B. MILLER
EDWARD C. RANEY, *Chairman*

REPORT OF AWARDS COMMITTEE, TERRESTRIAL PUBLICATIONS, MARCH, 1956

The committee has considered a wide variety of publications for award and honorable mention. We have solicited the advice of numerous colleagues; we have reviewed the policies and decisions of past committees; we have taken account of suggestions from the Committee on Awards Procedure; and we have tried to keep in mind what we thought to be the desires of The Society.

Perhaps our chief finding is that there is a wealth of excellent papers from which to choose. We could have made good use of fully a dozen awards. We cannot help feeling that the young profession of wildlife is in a far sounder, healthier condition than the frequency of criticisms and complaints would indicate. Indeed, the frequency and vehemence of the criticisms are signs that the profession is suffering growing pains and not dry rot.

The committee decided to make the Terrestrial Publication Award to the best research report published in the form of a book or monograph and to award Honorable Mention to the best work of synthesis. We also hoped to make Honorable Mention of the best journal article. But journal articles appear in such profusion and variety that the committee was unable to make a selection in the time available. No journal article was suggested by more than one member or adviser of the committee.

In the other two categories, the greatest question was how many publications should receive Honorable Mention. Here we were guided by instructions from the Committee on Awards Procedure to keep Honorable Mentions at a minimum, and by our own feeling that it would be unfair to select just a few of the many fine publications for this honor. The works that we have selected are all to be regarded as the outstanding publications in these fields.

The committee has selected as the outstanding report on wildlife research and management the book by Lyle K. Sowls, 1955, Prairie ducks, a study of their vehavior, ecology and management. Stackpole Co., Harrisburg, Pa., xii+193 p., 47 figs. This publication is based on a large body of long-term, deep-digging, original research. It is characterised by thoroughness and by adequacy of data and analysis. It is important to both practical management and fundamental concepts. It is written in clear, simple, concise style.

For the best work of synthesis, we wish to extend Honorable Mention and high praise to the monumental publication by A. W. Schorger, 1955, The passenger pigeon, its natural history and extinction. University of Wisconsin Press, xiii+424 p., illus. This volume, many years in preparation, is an admirable reconstruction of the biology of an extinct species. There can be no doubt that it is the result of one of the greatest tasks of bibliographic searching, compilation of data, and analysis of conflicting reports ever performed in the wildlife field.

Two highly significant and stimulating works on the facts and theories of animal population phenomena have appeared during the biennium. We believe that although these volumes are not precisely of a type of publication for which the Terrestrial Publication Award is intended, they are of unquestionable importance in wildlife biology.

We have decided, therefore, to give them Honorable Mention. One of these is the book by H. G. Andrewartha and L. C. Birch, 1954, The distribution and abundance of animals. University of Chicago Press, xv+782 p., illus. The other is the book by David Lack, 1954, The natural regulation of animal numbers. Oxford University Press, viii3+43 p., 52 figs. Both books are landmarks in their field and we recommend them to all serious students of population dynamics.

Respectfully submitted,
WILLIAM H. ELDER
DAVID A. MUNRO
ADOLPH MURIE
WILLIAM G. SHELDON
WILLIAM H. STICKEL,
Chairman

REPORT OF THE AWARD COMMITTEE ON CONSERVATION EDUCATION, MARCH, 1956

The Committee, having reviewed material nominated by Society members and others, recommends two works for the 1955 Conservation Education Award.

Ralph A. MacMullan and Oscar Warbach are recommended as author and illustrator of the booklet, "*The Life and Times of Michigan Pheasants*," published in 1954 by the Michigan Department of Conservation. These men have combined their talents to produce a publication especially effective in conveying pheasant management principles to the general public. This appealing booklet has been very popular; there were requests for sixty thousand copies in the first few months following its publication.

Benjamin Draper and Dr. Earl S. Hearld also are recommended for their television program "*Science in Action*," of which they serve as Executive Producer and Program Host, respectively. The program, owned and produced by the California Academy of Sciences, is produced live in San Francisco 39 weeks of the year, and since September 1955, has been seen in other parts of the country. The programs include a wide variety of science subjects, but at least one topic in wildlife conservation or an allied field appears in each 13-week series.

Mr. Draper, who has been with the program since its inception, heads a staff of writers, artists, and specialists who devote full time to producing the shows. Dr. Hearld, Curator of Aquatic Biology at the Academy's Steinhart Aquarium, appears on every episode as program host. In this capacity he has become a well known television personality and has been acclaimed widely for his direct and sincere presentation. Viewing "*Science in Action*" is recognized as a family activity and the program is followed in schools and integrated with classroom discussions. It has won every major poll in San Francisco since it has been on the air.

For honorable mention, The Committee recommends Charles W. Schwartz, for his outstanding and well received film production, "*Cottontail*," and Pieter Fosburgh, Editor of "*The New York State Conservationist*."

LEONARD E. FOOTE
MICHAEL HUDOBA
W. K. THOMPSON
ROBERT G. WINGARD
HARLAN B. BRUMSTED,
Chairman

REPORT OF THE EMPLOYMENT COMMITTEE, MARCH, 1956

Questionnaires on college enrollment and graduates were returned by 55 colleges and universities. Tallies of employment were received from conservation agencies representing 41 states, 5 provinces, the federal governments of the United States, Canada, Hawaii, and Puerto Rico.

Total college enrollments apparently were up 38% over the previous year but more schools (55 rather than 45 last year) reported for the present period which ended September 1955. The increase on a per school basis was 14%. Comparisons between enrollments over the seven year period of committee surveys may be biased by (1) an increased present-day reporting of underclassmen not recognized in earlier days as wildlife majors, (2) an increased proportion of fisheries majors not included in the early surveys, and (3) a more thorough coverage of educational institutions in recent years. Yearly totals of graduates may be a better index of trends in student abundance than are total enrollments. It is recommended, however, that tabulations of student enrollments in the various schools continue to be

published each year by the committee for the benefit of educators in the field.

There were 421 graduates at all levels during the year. This compares with a high of 633 in 1949–50 and lows of 369 and 374 in 1948–49, and 1953–54 respectively. Percentages of 1954–55 graduates known to have secured fish or wildlife jobs were: B.S. 30%, M.S. 73%, Ph.D. 60%. Forty-one per cent of graduates at all levels either entered military service or returned to school. Nine per cent took teaching jobs outside the wildlife field. For those known to have accepted fisheries or wildlife jobs, 50% took positions with state or provincial governments, 18% with federal agencies, 29% with schools, and 3% with private organizations.

The proportion of wildlife graduates awarded M.S. degrees has increased from 19% in 1948–49 and 1949–50 to 27%–30% during the last four years. Bachelor of Science graduates consequently have decreased from about 76% in the 1948–50 period to 57% during 1954–55. Doctors of Philosophy remained between four and seven per cent of the total but jumped to 14% in 1954–55.

During 1954–55, 119 fish biologist, 98 game technicians, 223 conservation officers, and 27 education people were hired. Opportunities for conservation officers seemed especially good. A special question was asked employing agencies, "Do you anticipate an increased opportunity in your organization for university-trained conservation officers (warden)"? Thirty of our 38 U.S. agencies said, "yes." Four of five Canadian replies said, "no." This may be the time when progressive states should press for professional training for those positions.

Increases in game and fish technician positions were forecast by about 50% of the state agencies replying to the questionnaire, while the other 50% looked to "no change." No one foresaw a decrease. For conservation officers and public relations positions, percentages predicting increases were 34% and 44% respectively. There was one tally for a decrease in conservation officers.

The several states, territories, and provinces required prior legal residence in the various job categories as follows:

Game Technicians: California, Colorado, Indiana, New York, Oklahoma, Oregon, British Columbia.

Fish Technicians: Colorado, Indiana, New York, Oklahoma, British Columbia, Hawaii.

Conservation Officers: California, Colorado, Delaware, Illinois, Indiana, Iowa, Kentucky, Missouri, Maryland, Michigan, Maine, New York, North Carolina, Oklahoma, Pennsylvania, Rhode Island, Virginia, West Virginia, Wisconsin, British Columbia, Hawaii.

Information-education Personnel: California, Colorado, Indiana, Michigan, New York, Oklahoma, Oregon, Rhode Island, British Columbia.

No Replies: Louisiana, Massachusetts, Minnesota, Mississippi, Montana, South Dakota, Wyoming, Newfoundland, New Brunswick, Prince Edward Island, Quebec, Alberta, Yukon.

A special study of salaries was begun late in the year by Dr. Leslie Glasgow. It will be published separately.

Respectfully submitted,
LESLIE L. GLASGOW
RAYMOND E. JOHNSON
THOMAS L. KIMBALL
V. E. F. SOLMAN
GEORGE A. PETRIDES,
Chairman

TABLE 1.—DISTRIBUTION OF 1954–55 FISHERIES AND WILDLIFE ENROLLMENT BY CLASSES AND SCHOOLS

Name of Institution	Underclassmen	Upperclassmen	M.S.	Ph.D.	Totals
Alabama Polytech. Inst.	8	8	1	2	22[1]
Alaska, Univ.	18	6	5	0	29
Arizona, Univ.	23	9	4	0	36
Arizona State College	1	1	0	0	2
British Columbia, Univ.	*	13	12	12	37
Calif. Univ. (Berkeley)	*	19	2	8	29
Calif. Univ. (Los Angeles)	*	7	1	8	16
Calif. State Poly. College	6	4	0	0	10
Colorado A. & M. College	23	21	16	0	60
Connecticut, Univ.	14	4	1	0	19
Delaware, Univ. Mar. Lab.	0	0	3	1	4
Florida, Univ.	*	0	0	**	0
Florida State Univ.	**	**	3	2	5
Georgia, Univ.[2]	16	12	4	5	37

TABLE 1—(*continued*

Name of Institution	Underclassmen	Upperclassmen	M.S.	Ph.D.	Totals
Humboldt St. College	70	64	3	**	137
Idaho, Univ.	*	16	7	**	23
Illinois, Univ.[2]	*	17	2	1	20
Indiana Univ.[3]	*	1	0	7	8
Iowa State College	18	12	4	8	42
Kansas, Univ.[5]	32	11	*	*	64
Louisiana State Univ.	0	0	0	0	0
Maine, Univ.	15	21	3	0	39
Massachusetts, Univ.	19	17	5	0	41
Miami, Univ.	**	**	8	0	8
Michigan State Univ.	77	35	13	8	134[1]
Michigan, Univ.	16	18	16	11	61
Minnesota, Univ.	31	8	3	5	47
Missouri, Univ.	39?	39	12	3	83
Montana State College	19	6	6	0	31
Montana State Univ.	53	26	4	0	83
New Hampshire, Univ.	17	9	0	0	26
N.Y. St. Coll. of Agr. (Cornell)	37	50	8	18	103
N.Y. St. Univ. (Syracuse)	**	**	4	6	10
N. Carolina State College	15	16	7	2	40
Ohio State Univ.	38	38	7	5	88
Oklahoma A. & M.	11	16	6	6	39
Ontario Agr. College	*	5	1	0	6
Oregon State College	114	55	21	3	193
Pacific Mar. Station (Calif.)	0	1	6	1	8
Pennsylvania State Univ.	0	0	11	3	14
Purdue Univ.	*	2	0	1	5
Rhode Island, Univ.	**	**	5	0	5
San Jose State College	27	13	0	0	40
Scripps Inst. Oceanog.	**	**	0	0	0
South Dakota State College	59	20	**	**	79
Southern Illinois Univ.	*	9	13	0	21
Texas A. & M.	38	11	3	2	54
Texas, Univ.	**	**	0	0	0
Toronto, Univ.	**	**	13[4]	2[4]	15[4]
Utah State Agr. College	54	32	22	8	116
Virginia Polytech. Inst.[3]	29[4]	16[4]	3	2	50[4]
Washington State College	19	9	2	5	35
Washington, Univ.	53	28	23	9	113
Wisconsin, Univ.	0	0	11	10	21
Wyoming, Univ.	14	3	2	0	19
Totals (55 Schools)	1023	717	306	164	2231

No Replies From: University of Oklahoma, University of West Virginia.
* Unknown.
** Stated as not offered.
[1] Freshmen and Sophomores combined.
[3] Includes special students.
[4] Includes students working in related fields.
[4] Juniors and Seniors combined.
[5] Limnology and Fisheries work only.

TABLE 2.—EMPLOYMENT SELECTION BY 1954–55 GRADUATES ACCORDING TO DEGREES RECEIVED

Employment Category	B.S.	M.S.	Ph.D.	Totals	Per cent
Game Research	7	14	5	26	6.2
Game Management	18	23	1	42	10.0
Fish Research	17	16	14	47	11.2
Fish Management	20	13	1	34	8.1
Game and Fish Management	0	0	0	0	0
Law enforcement	2	1	0	3	0.7
Public Relations	1	4	0	5	1.2
Teaching Game and Fish	7	6	14	27	6.4
Other Teaching	16	5	16	37	8.8
Back in School	64	33	3	100	23.7
Military Service	61	8	3	72	17.1
Other Employment or Unknown	27	0	1	28	6.6
Totals	240	123	58	421	100.0

Employment by Type of Agency:
State or provinical **110** Federal **40** Educational Institutions **64**
Private Organization **7** Students, Military, etc. **200**

TABLE 3.—ANTICIPATED EMPLOYMENT TRENDS OF STATE AND PROVINCIAL OFFICIALS

Category	To Increase	No Change	To Decrease
Game Technicians	21	23	0
Fish Technicians	22	21	0
Conservation Officers	14	26	1
Public Relations; Education	18	23	0

Totals
137
23
20
8
42
64
0
39
41
8
134[3]
61
47
83
31
83
26
103
10
40
88
39
6
193
8
14
5
5
40
0
79
21
54
0
15[4]
116
50[4]
35
113
21
19
2231

ED

Per cent
6.2
10.0
11.2
8.1
0
0.7
1.2
6.4
8.8
23.7
17.1
6.6
100.0

ecrease

0
0
1
0